بسم الله الرحمن الرحيم

Assessment of land cover change and changes in species composition and their environmental impacts at Oil industry Adar yale and Paloich area (Upper Nile State)

A thesis submitted for degree of Ph

By

Osama Bashir Mohammed Ali

B.sc Forestry (1988)

M.sc Forestry (2002)

Supervisor

Dr.Elnour Abdalla Elsidig

Department of Forest Management

Faculty of Forestry

University of Khartoum

December 2007

Dedication

To my father and mother

To my wife

To my son and daughters

To my brothers, to my sisters

To my friends

Osama bashir

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

Acknowledgement

My acknowledgement to all people that have made this thesis possible. I must ask to be allowed to express my sincere gratitude to my supervisor Dr. E. A. Elsiddig, Khartoum University, Faculty of Forestry to whom I am really indebted for his close supervision, helpful advice and fruitful criticism throughout the course of my study.

To my close friends and colleges who show the meaning of honor, Mr. Osama Mahgoub and all staff of Petro dar oil company. Any attempt to acknowledge all people who have contributed to preparation and execution of this dissertation will remain unsatisfactory, I therefore will record my immeasurable appreciation to all those who have directly or indirectly participated and also to those who have said as they were the real donors of hope and push. Whose keen interest in the subject has paved the way for this study. To Mr. Alyas Daak, University of Khartoum, Faculty of Forestry.

Finally, my acknowledgement would be left incomplete if I failed to thank my family whose patience created a healthy environment for the work. I therefore dedicate this work to them and to my parents.

Abstract

The study was based on application of remote sensing techniques and GIS in combination with ground survey to detect forest cover changes in Upper Nile state. Assessment of forest changes was carried in Adar yale and Paloich area for the period 1994 to 2004, covering an area of (1918220) hectares. The remote sensing images based on Land Sat of type TM (Thematic Mapper). The images were analyzed using the software of (EARDAS IMAGINE 8.5) by analyzing light layers to identify and locate vegetation position based on supervised analysis that is after image improvement. The images were classified into classes representing ecological factors. This is done with the objective of determining and locating the extent of changes within the land contained in the study area. Images were combined to facilitate identification of changes at any time and location. The inventory work was done by measuring 190 sample plots using 0.1 ha. The inventory was conducted during 2004.

Five land use categories were identified namely closed forests, open woodland, scattered trees and shrubs, agriculture land and bare land.

The results indicated dynamic changes within and between the land cover categories. While open woodland area increased over the ten years, the closed forest and the scattered trees and shrubs categories area was decreased. This resulted in a net decrease of the area of forest and trees cover by (8432.1 ha) equivalent to approximately 8% of the total area of forests and trees cover over ten years.

Deforestation on the other hand resulted in land transfer from forested land categories to agriculture land use, constituting the main cause of forest cover decline.

The study indicates that application of remote sensing technology is an efficient method to be applied for detection of land use changes with ground data information and the compatibility of ground survey with remote sensing. Land use categorization using either of the two systems resulted in similar classes. In addition, ground survey facilitated understanding of the species regeneration potential. The three species: *Acacia seyal*, *Acacia sengal* and *Balanites aegyptiaca* appeared to be the common species and provide possibility for regeneration in degraded areas.

ملخص الاطروحة

اعتمدت هذه الدراسة على استخدام تقنية الاستشعار عن بعد ونظم المعلومات الجغرافية والحصر الارضى لمعرفة تغيرات الغطاء النباتي فى منطقة اعالى النيل. و تم التقييم فى الغابات الطبيعية فى منطقة عدار ياى وبلوشى فى الفترة الزمنية من 1990 وحتى 2004 مساحة مجموعها 1918220 هكتار.

تمت الدراسة من خلال استخدام صور الأقمار الصناعية والتي التقطت لمنطقة الدراسة عام1994 وعام 2004 بواسطة القمر الصناعي landsate من نوعية TM (Thematic Mapper) وقد تم تحليل هذه الصور باستخدام برنامج (EARDAS IMAGINE 8.5) حيث تم تحليل طبقات الطيف الضوئي لمعرفة وتحديد مواقع الغطاء النباتى بإستخدام طريقة التصنيف الموجة بعد ان تم تحسين الصور من العوامل التى تؤثر على مستوى وضوحها ، تم تصنيف الصور الى اصناف تمثل العوامل البيئية المعنية بهذه الدراسة . بغرض تعيين وتحديد حجم التغيرات فى الاراضى فى منطقة الدراسة خلال الاعوام المعنية وتم عمل دمج بين الصور لمعرفة التغير من اى منطقة الى اخرى .وتعتبر منطقة عداربيى وفلوج من مناطق انتاج البترول المهمة فى السودان ولها تاثير سلبى على البئية وظاهرة الاحتباس الحرارى العالمى وتاثير امتصاص ثانى اكسيد الكربون غطت الدراسة كافة هذه الجوانب.

الحصر الغابى تم بقياس عدد 190 مربوع بواسطة نظام الحصر بمساحة للعينة تساوى 0.1 من الهكتار بنسبة تعادل 10 % ،تم الحصر فى عام 2004.

تم حصر المنطقة تحت الدراسة وتصنيفها لعدد خمسة انواع من الاستخدامات تبدا بالغابات المقفولة، الغابات المفتوحة، الاشجار المنتشرة، الاراضى الزراعية والاراضى الجرداء.

خلصت الدراسة ان هناك تغير مستمر فى استخدام الاراضى وان هذا التغير سببة الرئيسى الانسان، ابانت نتائج هذه الدراسة أن استخدام تقنيات ومعطيات صور الاقمار الاصطناعية من الطرق الفعالة التى يمكن استخدامها للتعرف على تغيرات الغطاء النباتي بالاضافة الى الحصر الغابى حيث اوضحت الدراسة تطابق النتائج المستخلصة من كلا الطرقتين، كما اوضحت الدراسة

بـان الحـصـر الغـابى مهم لمعرفـة اتجاهـات النمـو لاشـجار الطلـح، الـهشاب والـهجليج التـى يمكـن ان تستخدم فى اعادة الغطاء الشجرى.

CHAPTER ONE

Introduction

1.1 Introduction

Sudan exhibits a variety of ecological regions ranging from desert in the north to tropical forests in the south. Between the two extreme ecological zones there are semi-arid areas, short grass savanna, tall grass savannas and swamps including the Sudd, the permanent swap in the flood plains of Southern Sudan. The country also has great varieties of soils ranging from pure sands through highly fertile silty soils to heavy cracking clays. Likewise the climate condition is also diverse with nearly zero precipitation in most of the desert areas in north to equatorial rainfall with more than 1500 mm annually.

The economy of Sudan is based on agriculture, mainly crop production and livestock raising. The country also produces about 80% of world supply of Gum Arabic. Industrial activities in the country include textile manufacturing and processing of agricultural and forest products. There is also sugar industry as well as mining industry on chrome, asbestos, gold, gypsum as well as quarrying limestone for cement, gravel and sand for building and brick making from Nile silt. Oil exploration of discovered reserves is now the main priority of Sudan Government and accordingly major activities are now taking place.

Sudan is the largest African country, covering an area of almost one million square miles (94.8% land and 5.2% water) equivalent to 3.8% of the land area of the African continent. Sudan shares borders with nine African and Arab countries (Facts on Sudan. 2000). Geographically Sudan is situated in the middle of the northern part of the continent with upper left coordinate's latitudes 3ºN and 23º N and lower right coordinates longitudes 22ºE and 38º E. The country population is estimated at approximately 36.00 million inhabitants with annual growth rate of 2.71 % (El-Moghraby, 2006).

Sudan extends over different climatic regions (Table1.1) which are mostly governed by rainfall. They are ranging from desert in the north (0 - 100 mm rainfall per annum), to semi-desert, and savanna in the center (200 - 850 mm rainfall per annum), and equatorial in the South (up to 1500 mm per annumm). Summer is from March to July and coincides with the rainy season as the temperatures can reach as high values as 45 degrees Celsius during the day. Winter months are from November to January and temperature can drop to 4 degrees Celsius at night.

Sudan is moderately forested with around 17% of total land area (FAO 2001). In late 1970s FAO estimated that the countries forest and woodlands totaled about 915.0 square Kilometers, or 38.5 percent of the land area. Demand for forest products, mainly fuel wood and charcoal was steadily increasing during the last ten years as forest products are extensively used as a major source of energy for more than 80% of the population (FNC, 2003). The country also produces sawn wood, but in insufficient quantities to meet domestic demand. Modest quantities of wood and paper products are imported. The productive forests extend below the zone of desert encroachment to the southern border.

They included the savanna woodlands of the central and western parts of the country, dominated by various species of acacia, among them is *Acacia senegal*. Sudan is the principal source of gum Arabic, the second largest export product estimated as 5% in 1996 and accounting for 80 percent of the world's supply (Facts on Sudan, 2003). Sudan is also one of the world's main producers of olibanum resin (FAO, 2000).

Although Sudan had a large quantity of natural resources, the rate of annual forest cover change is said to be considerable. The main factors that contribute in the decrease of forest cover are lack of sound management, absence of land use plans, population pressure, desertification, mechanized agriculture in dry land, traditional shifting cultivation and fire in some places (FNC, 2003).

Table 1.1 Vegetation of Sudan by regions

Vegetation	Rainfall	Area in hectares
Desert	0-75 mm	90 208 00 (36 %)
Semi desert	75-300 mm	50111000 (20 %)
Low rainfall savannah	300-900 mm	60139000 (24 %)
high rainfall savannah	900-1500 mm	30070000 (12 %)
Flood plains mountain vegetation	1500-2000mm	20046000 (8 %)

(Source: FAO 2001)

1.2 Climatic zones

Sudan is characterized by a wide range of climate zones, which vary from desert in the northern part of Sudan, where it seldom rains, through a southward belt of varying summer rainfall, to an almost equatorial type of rain in the extreme south west, where the dry season is very short (Table1.1).

1.3 Land-use in Sudan

In central Sudan the following divisions of land use can be observed (Table 1.2).

Table (1.2) land use in Sudan

Item	Area in (000 Hectare)
Total area	2505.8
Land area	2374.43
Area under water	129.86
Arable land	840.34
Cultivated land	174.71
Uncultivated land	665.63
Forest and wood land	643.60
Other	495.69

(Source: FAO 2001)

1.4 Forests in Sudan

Since the early 1950s, extensive areas of woodland and forest have been converted to agricultural use. Large areas of land classifiable as woodland have been cleared for the development of large-scale mechanized rainfed farming in central Sudan States, and smaller amounts in upper Nile and southern Kurdufan States.

Although Sudan had a large quantity of natural forests, much of it has been deforested. In the late 1970s, it was estimated that the country's forests and woodlands totaled about 915,000 square kilometers, or 38.5 percent of the land area of Sudan. This figure was based on the broad definition of forest and woodland as any area of vegetation dominated by trees of any size. An estimate in the mid-1980s by the Forestry Administration, however, established the total forest cover at about 584,360 square kilometers, or 24.6 percent of the country's land area. More than 129,000 square kilometers (about one quarter) of this amount were located in the dry and semiarid regions of northern Sudan.

The forests were considered valuable, chiefly as protection for the land against desertification and environmental degradation but they also served as a source of fuel for pastoral and sedentary people in those regions. The continued population pressure on the land has resulted in an accelerated destruction of forestland. The loss of forestland in the marginal areas of the north, accelerated by mechanized farming and by drought, resulted in a steady encroachment of the Sahara southward at about ten kilometers a year in the 1980s.

The productive forests extended below the zone of desert encroachment to the southern border. It included the savanna woodlands of the central and western parts of the country, which were dominated by various species of acacia, among them *Acacia senegal*, the principal source of gum Arabic.

The principal area of productive forest and woodland, however, was in the more moist southern part of the country. Covering an area of more than 200,000 square kilometers and consisting mainly of broadleaf deciduous hardwoods, it remained largely undeveloped.

Plantations established by the government Forestry Administration in the mid-1970s totaled about 16,000 hectares of hardwoods and 500 to 600 hectares of softwoods, most were in the south. They included stands of teak and in the higher elevations of the Imatong Mountains, exotic pines. Eucalyptus stands had also been established in the irrigated agricultural areas to serve as windbreaks and to supply firewood.

A gradually increasing forest reserve has been developed, and by the mid1970s it covered more than 13,000 square kilometers. Additional protection of forest and woodland areas was provided by several national parks and game reserves that encompassed 54,000 square kilometers.

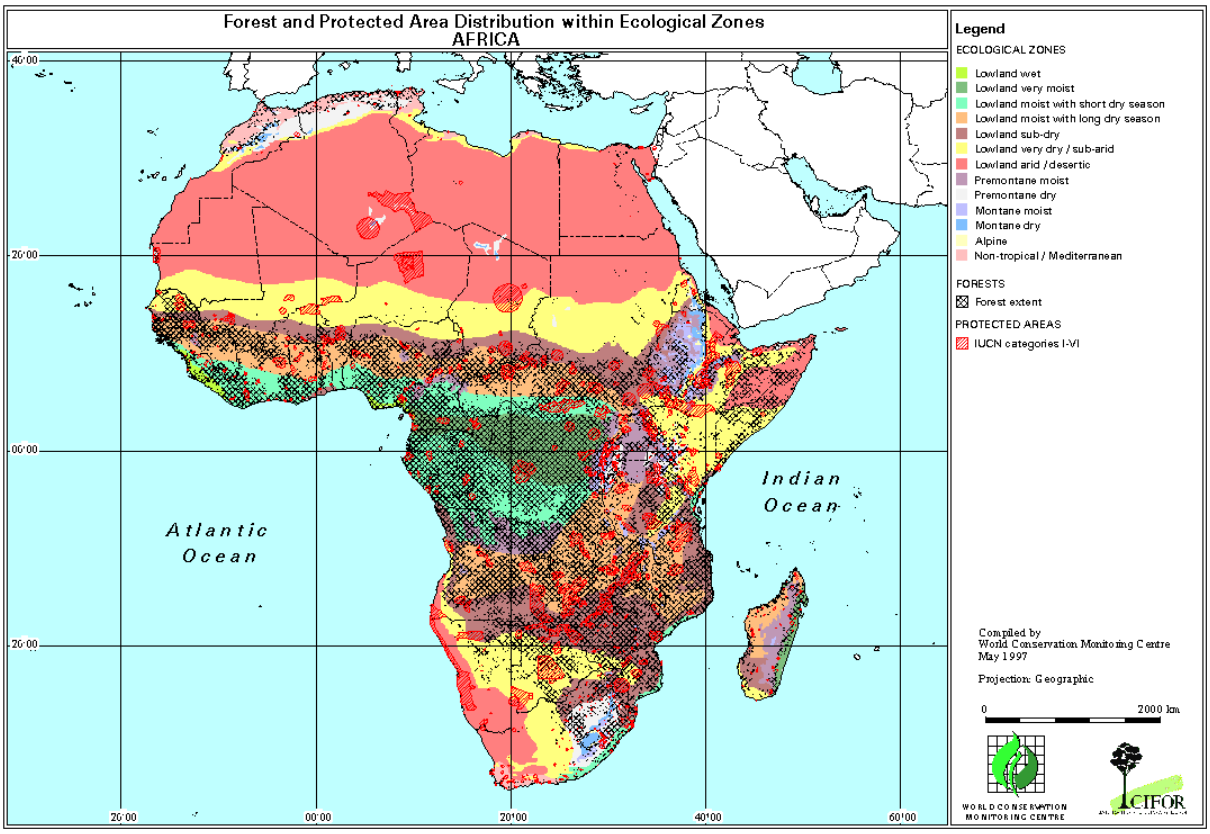


Figure1.1 distribution of protected forest within Africa (CIFOR, 2003).

1.5 Population

The population density in Sudan is about 12 persons /km². This figure gives a false indicator of population distribution when cultivable/ arable land is considered. The population density is as high as 370 persons/km² in land presently cultivated along the Nile. Approximately half population is estimated living on just 15% of the land.

Main feature of population is rapid growth rate of 2.05 % . However, a declining trend of mortality rate influences the population growth rate. The annual rate of growth of the population in urban areas is 5.6–6% versus 2%

in rural areas. An important demographic dimension is the impact on the age structure of the population; about 38.9% of the total population is under 15 years of age. This young population structure implies heavy burden on social services, especially on education and health. During the next 20 years these people will likely form an increasingly heavy consumption base for forests products and services. However, at the same time young population structure will promise a big development potential in terms of labour market during the next two decades. The projection of UN reflects that urbanisation will increase by 110%, so expansion of human settlements will be at the expense of tree cover. (A. A. Mohammed , 2003)

1.6 Problem Statement

Sustainable forest management can be described as the practice of meeting the forest resource needs and values for present and future generations. Assessment and monitoring of forest resources are becoming essential steps towards sustainable forest management.

Criteria associated with many indicators deal with biological aspects of forests measured as changes in such as diversity, productivity and contribution to carbon storage. Few criteria deal with socio-economic aspects as well as legal institutional aspects.

Biological diversity, measured in species composition expressed in relative values, constitute an important criterion of forest richness. Forest productivity changing trends measured in forest extent, area, stand age\ area and size\ area relationships provide means for assessment and monitoring e,g *Acacia seyal* mixed forest decline in average dbh, and number of species and their relative values changes.

National forest reserves in the area oil industry are described as fully stocked at the time of oil exploration and reservation processing. However, their traditional mamegement is limited to protection under control of forest guards. The management approach is based on prevention of the local communities from access, expect for limited benefits.

The local communities illegally enter the forest together with oil companies for various purposes (wood, nonwood products, agriculture, grazing and land) and might have caused forest degradation. Pilot projects introduced the concept of people involvement in some activities based on mutual benefits. It is assumed that the approach of people in treating the forests resulted in some changes to the forest that might have improved the conditions of the deteriorating forest reserves, as well as the oil industry.

1.7 Hypotheses.

Oil company involvement in management of natural forest reserves improves the forest composition, structure and productivity.

1.8 Objectives.

1.8.1 Overall objective:

To evaluate methods of controling the degradation of natural forest reserves on the basis of oil company involvement.

1.8.2 Specific objectives:

1-To evalute the trends of changes in natural forests reserves, their structure, composition and productivity over time.

2-To address the use of biological criteria and indicators associated with natural stands development.

3-To set multipurpose functions of natural forest reserves in relation to community needs.

4-To address environmental policies and management at local levels to be compatible with the environmental strategy of Sudan.

CHAPTER TWO

Literature review

2.1 Definition of sustainable forest management.

A definition of the present day understanding of the term sustainable forest management (SFM) was developed by the Ministerial Conference on the Protection of Forests in Europe (MCPFE,1998), and has since been adopted by the Food and Agriculture Organization FAO, (2001). It defines sustainable forest management as. “The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems”.

Kokusai, (1996) stated, in simpler terms, the concept can be described as the attainment of balance between society's increasing demands for forest products and benefits, and the preservation of forest health and diversity. This balance is critical to the survival of forests, and to the prosperity of forest-dependent communities.

For forest managers, sustainably managing a particular forest tract means determining, in a tangible way, how to use it today to ensure similar benefits, health and productivity in the future. Forest managers must assess and integrate a wide array of sometimes conflicting factors - commercial and non-commercial values, environmental considerations, community needs, and even global impact - to produce sound forest plans. In most cases, forest managers develop their forest plans in consultation with citizens, businesses, organizations and other interested parties in and around the forest tract being managed (Oosterman and Wanabakti, 2000).

Because forests and societies are in constant flux, the desired outcome of sustainable forest management is not a fixed one. What constitutes a sustainably managed forest will change over time as values held by the public change (C.C.W, 2002).

2.2 Objective and aim of SFM

Dargavel, (1995) said that aims to ensure that the goods and services derived from the forest meet present day needs also consider securing their continued availability and contribution to long-term development. In its broadest sense, forest management encompasses the administrative, legal, technical, economic, social and environmental aspects of the conservation and use of forests. It implies various degrees of deliberate human intervention, ranging from actions aimed at safeguarding and maintaining the forest ecosystem and its functions, to favoring specific socially or economically valuable species or groups of species for the improved production of goods and services.

Plantinga *et al*. (1999) mentioned that many of the world's forests and woodlands, however, especially in the tropics and subtropics, are still not managed in accordance with the Forest Principles. Since 1992, these principles were adopted based on the United Nations Conference on Environment and Development (UNCED, 1992).

Many developing countries have inadequate funding and human resources for the preparation, implementation and monitoring of forest management plans, and lack mechanisms to ensure the participation and involvement of all stakeholders in forest planning and development. Where forest management plans exist, they are frequently limited to ensuring sustained production of wood, without due concern for non-wood products and services or social and environmental values. (Parks, and Hardie, 1995). In addition, many countries lack appropriate forest legislation, regulation and incentives to promote sustainable forest management practices.

FAO, (1994) helps member countries to overcome these constraints through the provision of information and policy advice and through institutional and technical capacity-building activities. FAO, (1995) collects analyses and disseminates information; prepares manuals and guidelines; and organizes workshops and seminars that facilitate the dissemination of best practices and the exchange of experiences. Field projects are implemented in all types of natural forests. They also address emergency situations caused by natural disasters or the adverse effects of human activities, and offer opportunities for hands-on training.

At the national level, FAO, (1996) supports initiatives for the development and implementation of criteria and indicators to define clearly the elements of sustainable forest management and to monitor progress towards it. At the field level, FAO, (2000) helps identify, test and promote innovative forest management approaches and techniques, e.g. through support for model and demonstration forests.

2.3 Improving silvicultural and operational solutions for achieving sustainable management

Dixon *et al.* (1994) said that the concept of sustainable forest management implies the stewardship and use of forests to provide a range of benefits over time. International agreements and national policies require foresters to demonstrate that their forestry practices meet independent criteria of sustainability. In Britain, as elsewhere, the increasing emphasis upon sustainability has led to the promotion of 'multiple-use' management which generally means developing varied forests containing stands of different species, ages and structures. Such developments represent a major challenge to foresters because many existing about revising forests comprise regular stands of a small number of species which are designed to maximize wood production. The need to rethink existing forestry practices to meet changing objectives lies at the heart of research into sustainable forest management.

With this in mind, Forest Research units are exploring new approaches to woodland management and protection to support policies aiming to increase the species and structural variability of forests. Areas under investigation include:

- Greater use of natural regeneration.
- The role of continuous cover forestry.

2.4 Integrated forest vegetation management

Harmer, and Willoughby, (2007), stated that vegetation management is a vital component of sustainable woodland management. Woodland management can have many objectives, such as for example, timber or wood fuel production, habitat restoration, protecting or enhancing biodiversity, or providing a resource for recreation, and this can be achieved using a variety of management systems, such as continuous cover forestry, clear felling and replanting, or restoration.

Stokes, and Willoughby, (2007) mentioned that whatever the objective or management system adopted, at some stage a manager will need to favor the development of trees and other desirable vegetation over less desirable, competitive plants. Without suitable vegetation management, the primary objectives for the woodland are often unachievable.

2.5 Concept of SFM and term of achievement procedure

Nour and Galante (2003), stated that, sustainable forest management (SFM) has been, since the UNCED in Rio in 1992, a leading concept in international deliberations and work. The result today is a broad consensus on principles, guidelines, criteria and indicators for SFM on international governmental level. One such process is the Ministerial Conference on the Protection of Forests in Europe (MCPFE), ongoing process in which hundreds of experts from a very wide range of stakeholder groups have been involved. Other similar intergovernmental processes, which can serve as a basis for the development of forest certification schemes, are:

- Montreal process.
- Near East Process,
- Lepaterique Process,
- Regional Initiative of Dry Forests in Asia,
- ITTO Criteria and Indicators for Sustainable Management of Natural Tropical Forests,

- Criteria and Indicators for Sustainable Management in Dry-zone Africa,
- Tarapoto Proposal: Criteria and Indicators for the Sustainable Management of Amazonian Forests,
- African Timber Organization Principles, Criteria and Indicators for Sustainable Management of Natural Forests.

For the forest certification purposes, each country develops in a broad multi-stakeholder process, its own national (or regional) standard for sustainable forest management based on the MCPFE guidelines or other intergovernmental processes promoting SFM, such as the national laws and regulations and the core International Labour Organisation (ILO) conventions and other international conventions ratified by the country in question such as the Convention on Biological Diversity, Kyoto Protocol, Convention on International Trade on Endangered Species of Wild Fauna and the Flora and Biosafety Protocol.

2.6 Criteria and indicators

Appanah *et al.* (2000), explained that criteria and indicators are policy instruments by which progress towards implementing sustainable forest management may be evaluated and reported on. Criteria define and characterize the essential elements, as well as a set of conditions or processes, by which sustainable forest management may be assessed.

Periodically measured indicators reveal the direction of change with respect to each criterion, (CIFOR, 2003).

Finegan and Campos (2000) said that criteria and indicators for adressing sustainable forest management are widely used and many countries produce national reports that assess their progress toward sustainable forest management. According to ITTO, (1998) there are nine international and regional criteria and indicators initiatives, which collectively involve more than 150 countries.

Three of the more advanced initiatives are those of the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests also called the Montreal Process (1995), the Ministerial Conference for the Protection of Forests in Europe, and the International Tropical Timber Organization. Countries who are members of the same initiative usually agree to produce reports at the same time and using the same indicators, ITTO, (2002). Within countries, at the management unit level, efforts have also been directed at developing local level criteria and indicators of sustainable forest management, (Poore, 1989).

The Center for International Forestry Research, the International Model Forest Network and researchers at the University of British Columbia had developed a number of tools and techniques to help forest-dependent communities develop their own local level criteria and indicators. Criteria and Indicators also form the basis of the Canadian Standards Association certification standard for sustainable forest management. There appears to be growing international consensus on the key elements of sustainable forest management.

Saamin and Rahaman (1998) monitioned seven common thematic areas of sustainable forest management have emerged based on the criteria of the nine ongoing regional and international criteria and indicators initiatives. The seven thematic areas are:

- Extent of forest resources
- Biological diversity
- Forest health and vitality
- Productive functions and forest resources
- Protective functions of forest resources
- Socio-economic functions
- Legal, policy and institutional framework.

Haynes,*et al* . (2000), said that this consensus on common thematic areas (or criteria) effectively provides a common, implicit definition of sustainable forest management. The seven thematic areas were acknowledged by the international forest community at the fourth session of the United Nations Forum on Forests and the 16th session of the Committee on Forestry (CICI-2003).

2.7 Forest clearness

Stocking and Murnaghen (2001) stated the annual rate of change in total forest area (land with at least 10 per cent tree cover and 0.5 ha area) from 1990 to 2000 for the whole of Africa was estimated to be -0.74 per cent, equivalent to losing more than 5 million ha of forest a year.

In terms of area deforested during 1990-2000, Sudan tops the list with 9.6 million ha, followed by Zambia (8.5 million ha), Democratic Republic of Congo (5.3 million ha), Nigeria (4.0 million ha) and Zimbabwe (3.2 million ha). Only seven countries increased their forest areas over the same period (FAO, 2001).

2.8 Ecosystem approach

The Ecosystem Approach has been prominent on the agenda of the Convention on Biological Diversity CBD since 1995. The CBD, (2000) definition is as follows:

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Application of the ecosystem approach will help to reach a balance of the three objectives of the Convention. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompasses the essential structures, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

Sustainable forest management was recognized by parties to the (CBC, 2004) to be a concrete means of applying the Ecosystem Approach to forest ecosystems. The two concepts, sustainable forest management and the ecosystem approach, aim at promoting conservation and management practices which are environmentally, socially and economically sustainable, and which generate and maintain benefits for both present and future generations. In Europe, the MCPFE and the Council for the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) jointly recognized sustainable forest management to be consistent with the Ecosystem Approach in 2006, (Froylan *et al*. 2001).

2.9 Carbon dioxide (CO_2)

Coauthors, (2000) said that, carbon dioxide is incorporated into forests and forest soils by trees and other plants. Through photosynthesis, plants absorb carbon dioxide from the Earth's atmosphere.

A young forest, composed of growing trees, absorbs carbon dioxide and acts as a sink. Mature forests, made up of a mix of various aged trees as well as dead and decaying matter, may be carbon neutral above ground, (Ibid).

In the soil, however, the gradual build-up of slowly decaying organic material will continue to accumulate carbon, but at a slower rate than an immature forest. This accumulation of organic material in the form of (humus) in the forest floor only occurs below about 25 degrees Celsius,(IPCC, 2000). Above this temperature, humus is oxidized. Tropical jungles, for this reason, have very thin organic soils. The forest eco-system may eventually become carbon neutral. Forest fires release absorbed carbon back into the atmosphere.

This process is slow enough that in many cases the bog grows rapidly and fixes more carbon from the atmosphere than is released. Over time, the peat grows deeper. Peat bogs inter approximately one-quarter of the carbon stored in land plants and soils. Under some conditions, forests and peat bogs may become sources of CO_2, such as when a forest is flooded by the construction of a hydroelectric dam.

2.9.1 Carbon dioxide (CO_2) sinks

A carbon dioxide (CO_2) sink is a carbon reservoir that is increasing in size, and is the opposite of a carbon dioxide "source". The main natural sinks are (1) the oceans and (2) plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass and release oxygen into the atmosphere. This concept of CO_2 sinks has become more widely known because the Kyoto Protocol allows the use of carbon dioxide sinks as a form of carbon offset, (Coauthors, 2000).

2.9.2 Carbon sequestration

Coauthors (2001) said carbon sequestration is the term describing processes that remove carbon dioxide from the atmosphere. To help mitigate global warming, a variety of means of artificially capturing and storing carbon (while releasing oxygen) as well as of enhancing natural sequestration processes are being explored.

2.10 Forests as natural sequestration plants

Gibbard *et al*. (2005) said that forests are carbon stores, and they are carbon dioxide sinks when they are increasing in density or area. Tropical reforestation can mitigate global warming until all available land has been reforested with mature forests, (IPCC 2007). Trees only cool the planet if they are planted in the tropics.

William (2004), stated that in the United States the carbon dioxide is released mainly by combustion of fossil fuels (coal, oil and natural gas; and this adds great quantities to the atmosphere. The global cooling effect of carbon sequestration by forests is partially counterbalanced: For example, the planting of new forests may initially be a source of carbon dioxide emission when carbon from the soil is released into the atmosphere.

2.11 Carbon Storage in Trees

Moulton, and Richards, (1990), said that estimates of growing-stock volume in a forest area were converted to estimates of carbon storage in trees in a two stage processes. First, growing-stock volume was estimated in terms of total forest tree volume by multiplying by a ratio to account for the additional tree volume excluded from estimates of growing-stock volume: tops and branches, foliage, rough and rotten trees, small trees, stump sections, roots, and bark. Ratios were derived from two principal sources, a new nationwide biomass. Containing the estimates of above-ground biomass by tree component (Cost *et al* .1990, Koch , 1989). Separate ratios were derived for each of the regions or climatic zones to account for different tree form and to be consistent with the data used to the growing-stock volume,(IPCC, 1996).

The validity of this method rest the assumption that the ratio of total above-ground biomass to merchantable biomass (estimated in dry weight unit equivalent to the ratio of total above-ground volume to growing-stock volume (FRA, 1990). There is considerable variation in the ratios of total volume to growing-stock volume among regions and species groups.

The second step involved converting total tree volume cubic meter to carbon in kilo gram. Separate factors were developed for major forest types, for softwoods and hard woods within each forest type. The volume-to-carbon conversion was computed in two steps. First volume in cubic meter was converted to biomass in dry pounds by multiplying the number of cubic meter times the mean specific gravity. The second step was to multiply the biomass pounds by a factor to account for the average carbon content of the tree. Estimates of the carbon content used in past studies have generally ranged from 45 to 50 percent (Houghton *et al.* 1985). However, Koch (1989) found that, for the United States as a whole, the average percent carbon for softwoods was 52.1 % and for hardwoods was 49.1, with some slight regional variations. The final factors used to convert volume to carbon ranged from 11.41 to 17.76 for softwoods, and from 11.76 % to 19.82 % for hardwoods (FRA, 2000).

2.12 Remote Sensing in Sudan

This section provides an overview of remote sensing technology. Fundamentals of remote sensing and image interpretation are described in many texts, including NASA's Remote Sensing, the Canada Center for Remote Sensing and the International Society of Photogrammetric Engineering and Remote Sensing (ISPRS). The modern innovations in remote sensing technology (RS), Global Positioning Systems (GPS), and geographic Information System (GIS), have raised the opportunity to produce new maps with much easier way. Those systems replaced the map production that has been practiced as a process based on ground survey using compass, chain and ranging rods. This history of mapping in the Sudan reveals the same assumption as much of the produce maps has been produced during the last century only with the help of donors utilizing the capability of the Sudanese Survey department.

Development in remote sensing in Sudan provided new technological concepts towards the production of new map series especially for small and medium scale maps at scale that range between 1:200,000 and 1:500,000 leading to continuous monitoring, checking and updating of maps. Hence the production of a new series of the above scale of maps will efficiently serve the present demand for such maps to meet the expectations of the users from different sectors. (Gorani and Khair, 2005).

Modern space technology began with invention of the camera in early 1800s, and the first application in 1858 with a camera mounted on a balloon. During early 1900s cameras mounted on planes were used in reconnaissance surveys. The greatest Expansion of the use of space technology continued during the second half of the 20th century primarily for military reconnaissance surveys.

Applications of vegetation mapping and planning, then followed, getting use of the modern remote sensing technique, (Sherbinin, 2002)

Remote sensing provisions are based on utilization of the electromagnetic Radiation (EMR) (Janza, 1975). The utilization system is based on wavelengths ranging from the very short ones (the gamma ray region) to the long wavelengths (the radio region). The mechanism of features measurement in response to the electronic radiation receiver is described in many texts on remote sensing.

2.13 Remote sensing and land cover detection

Vegetation has been identified as one of the most biophysical parameter of terrestrial surfaces due to its specific role in geosphere- biosphere to be detected by remote sensing (Camphell 1996). Remote sensing techniques are used to characterize vegetation properties in order to facilitate classification into categories. describe the process of absorption of plant leaves in to red and blue range of electromagnetic spectrum, which allow for classification, (Ibid) .

The Normalized Difference Vegetation Index (NDVI), used in some studies is an example for land use classification and for biomass estimation (Kennedy, 1989).Remote sensing data provided facilities for inventory and analysis of land cover changes and cover dynamics. Such changes have occurred rapidly and involved large areas, especially in developing countries. Understanding the dynamics and causes of these changes is required in terms of establishing more efficient management of landscape at local regional levels (Moran *et al*., 1994). The importance of remote sensing in monitoring and mapping the changes in land cover is widely recognized and well developed in a wide variety of fields, (Ibid).

The remote sensing techniques taken over successive periods provides for identifying change in objects at the same location. Digital methods of change can be divided into either pre-classification (spectral change detection) or post classification (change detection) methods (Singh, 1989). The process requires the availability of imagery acquired at different dates, (of imagery upon which the same area of land can be observed).

The principle of land cover change detection is based on analysis of specific changes in spectral signatures of affected land surfaces, and are based on images differences (Weissmiller and Kistoof, 1977). When applying post classification change detection, two images of different dates are independently classified and labeled, and the area of change is then extracted through the direct comparison of the classification results (Colwell, 1981).

2.14 land degradation in Sudan

In countries as vast as the Sudan, the use of remote sensing technology is perhaps the only economically feasible way of surveying the natural resources and land degradation in several fields, (El siddig *et al*. 2005) Many studies of land degradation has been carried out in different ecological zones in Sudan, including desert and semi desert areas. Remote sensing was introduced in the Sudan in 1971 by the Food and Agricultural Organization (FAO), for surveying, mapping and development and associated with the Savannah Development project for reconnaissance of land and water resources in the southern part of the Blue Nile.

Application of remote sensing, GIS and spatial models in semi-arid Sudan was tackled by Olsson (1985) for study of desertification. The study indicated land degradation and severe decrease in agricultural crop yield and reflected in environmental degradation. Ahlcrona (1988) applied remote sensing for the study of impact of climate and man on the land transformation in Central Sudan.

Ali (1996) assessed and mapped desertification in Western part of Sudan using NDVI images showing that remotely sensed data gave good indicators of vegetation degradation throughout the period 1982 – 1994.

GIS Technology is being increasingly used for a host of applications. One of the key areas of application is monitoring the environmental degradation brought out by an increase in the anthropogenic activities resulting in the removal of the forest cover.

There have been fewer attempts to link remote sensing and socioeconomic data for the study of other land-cover conversions, e.g. from productive subsistence agricultural land to "degraded" land, or from natural vegetation and agriculture to urban land uses. Xu *et al*. (2000) studied the impact of urbanization on arable lands using a combination of remote sensing, census and economic data, concluding that rapidly growing economy was primarily responsible for the growth in urban structure on expence of green cover..

There has been some attention to the link between the social processes and the spatial patterns of deforestation have also been studied. Geist and Lambin (2001) summarize the research in the area of land sat and deforestation based on a statistical analysis of deforestation case studies. The results of their analysis show that, the geometric pattern of deforestation are commonly associated with large-scale clearing for commercial agriculture, large scale pasture, or industrial forestry plantation settlements.

2.15 Remote sensing application

Remote sensing has wide and useful applications including vegetation studies and cover detection, particularly in arid and savanna regions. Change detection has been applied for vegetation mapping, timber harvesting plans, urban sprawl detection, flood monitoring, mining and natural disaster damage, assessment. Specifically, change detection is used in agriculture for predicting crop yields and for global monitoring of food and fiber production (Cracknell and Hayes, 1991).

Forestry applications include inventory updating as well as fire and damage changes detection. The United Nations Food and Agriculture Organization have been using the change detection on satellite imagery since the early 1980's for the purpose of monitoring global changes in the forest conditions.

2.16 Image Processing

Jensen, (2000) defined the digital image processing as "fundamental methods of rectifying the remotely sensed data to map projection, enhancing the data, classifying the data into land use and land cover, and identifying change between dates of imagery.

Sabins and Floyd, (1996) and Jensen, (1996) stated that, none systematic distortions can be corrected by employing geographic features on the images called ground control points (GCPs), whose positions are known. Difference between actual GCP locations and their positions in the images are used to determine the geographic transformation required to restore the image. The original pixels are resampled to match the corrected using data from platform and knowledge of internal sensor distortion.

Image enhancement is the modification of an image to alter their impact on the viewer. Jensen, (1996) reported that, image enhancement algorithms are applied to remotely sensed data to improve the appearance of an image for human visual analysis or occasionally for subsequent machine analysis.

2.17 Image Classification

Image classification is defined as the process of sorting pixels into a finite number of classes or categories of data (ERDAS IMAGING, 1982). Normally multi spectral data are used to perform classification and the spectral pattern present within the data for each pixel is used as the numerical basis for categorization (Lillesand and Kiefer, 1994).

Two approaches are generally known: Supervised and non- supervised classification. In the former case a priori knowledge of the study area and the different classes is needed to establish training areas that represent each category. The latter involves algorithms that examine unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values (Lillesand and Kiefer, 1994).

2.18 Global Positioning System (GPS)

The global positioning system is a satellite based positioning and navigation system for obtaining quantified data on location in a terrain (ITC, 1997). It is also used in combination with the (GIS) for a wide range of applications, such as selection of ground control point (GCPs).

The heart of the GPS consists of 21 satellites and three spares circling the earth twice daily. These satellites are continuously sending signals that can be received with antenna. Because it is exactly known at what time the signal is sent from the satellite and at what time it is received by the receiver, the difference in time can be calculated. This difference is then used to compute the distance between the satellite and the receiver given the known travel speed of signal. A code is sent together with the signal, giving the exact location parameters of the satellites (ITC, 1997).

2 .19 Post- Classification Change Detection

This method avoids problems encountered at the pixel level (such as shadows and reflections) and requires both images to be individually rectified and classified before they can be compared pixel by pixel (Jensen, 1996). This pixel-by-pixel comparison is accomplished using a change detection matrix. Care must be taken to ensure that both classifications are as accurate as possible since any error that occurs in the classification will be carried over into the change detection. This method results in a base map that can be used for the next year. It identifies where the change has occurred and how much change has occurred.

However, producing a change map based on two classifications requires a little more ground work and the final change classification is only as the product of multiplying the accuracies of each individual classification (Stow *et al*. 1980).

2.20 Manual, on Screen Digitization of Change

On screen digitization is accomplished in the same fashion as photo interpretation, where two images (or photographs) are registered to a common base map and visually compared to manually identified changes based on size, shape, shadow and texture (Jensen,1996). This method is often the most feasible method for change detection, especially when other techniques fail to accurately identify changes.

2.21 Spectral Change Vector Analysis (CVA)

This technique uses change vectors to describe the direction and magnitude of the difference in pixel values between dates. A change has occurred if the vector surpasses a specific threshold value. The type of change that has occurred can determine the angle direction of the change vector. The type of change is then placed on a black and white base map of the region and the changed pixels are color coded according to their directions (Michalek *et al*. 2003).

Change vector analysis can indicate the relative magnitude and direction of the change. It can make use of both the spectral and temporal dimensions of the data and can analyze data in all the layers and process any number of spectral bands. This last feature is particularly useful because not all changes are easily identified in any band or spectral feature (Michalek *et al*. 1993).

Despite the benefits of the change vector analysis, (Chen *et al.* 2003) summarize a few drawbacks of this technique. Specifically, the image radiometry is particularly sensitive to the sensor system and environmental disturbance factors previously discussed. There is no automatic method for effectively determining the threshold between the change and no-change pixels. It is also difficult to discern between different phenomenological types of change when the number of bands involved in the change direction is large. In addition when TM data is used in a CVA, substantial changes need to occur before they will be detected (Michalek *et al.* 1993).

The CVA is valuable as a tool for locating areas of suspected habitat change for purpose of focusing more intensive field survey techniques (Michalek *et al*. 1993). It is also a more cost efficient and effective method for detecting change over large areas than other techniques (Michalek *et al*. 1993).

2.22 Sampling option.

Kleinn, (2002) explained that, sampling is employed for the assessment of most attributes gathered in National Forest Inventories (NFIs). Full-cover assessment by satellite imagery is technologically possible for only a few attributes (such as forest area and related variables). Forest inventory designers have done pioneering statistical work in sampling theory. In early NFIs, sampling was driven by a blend of statistical and practical considerations. The large set of attributes assessed in NFIs does not allow simple optimization of sampling and plot design.

Systematic sampling is the most frequently used sampling design in NFIs, sometimes in combination with stratification and/or other estimators. The most frequently applied plot design employs clusters of subplots; in temperate and boreal forests these tend to be fixed-area circular plots or point samples (a specific plot design used in forest inventory where a fixed plot area is not defined), while in tropical regions they tend to be elongated rectangular plots (strip plots). In some NFIs, however, for example in Switzerland and formerly in China, individual plots have been used rather than clusters of plots. (Unasylva, 2000).

New sampling techniques are constantly being developed, discussed and presented in forestry research. Some of the more recently described techniques, such as adaptive cluster sampling and importance sampling, allow impressive gains in precision for specific inventory questions. However, the established combination of systematic sampling with cluster plots does not yet seem to have a serious competitor. Adjustments of the cluster plot design for the assessment of particular attributes (for example, in the context of observing indicator variables for biological diversity, or for more efficient recording of rare objects) may have promise. Efficient integration of data from different sources, particularly integrating data from field samples with remote-sensing imagery, may be of benefit to NFIs (Schreuder, 2001).

CHAPTER THREE

Study area

3.1 Back ground.

South Sudan consists of the ten States of Sudan, formerly composing the provinces of Central Equatoria, East Equatoria, West Equatoria, North Bahr al Ghazal, West Bahr al Ghazal, Lakes, Warab, Jonglei, Unity, and Upper Nile (Figure 3.1).

3.2 location of the study area

The study area lies in mid-south of the Sudan, within the State of north Upper Nile, (Figure 3.2) Paloich and Adar yale (Figures 3.3 and 3.4) area about 560 Kilometres south of khartoum. Area about 53628 km^2 which is equivalent to 9% of the total area of south Sudan (589,745 km^2).

Southern Sudan has a rich forest flora. Trees are important in the livelihoods of the numerous tribes of the region, who use them for shelter, fuel, food, fodder, medicine and income generation. The gallery and depression forests contain valuable timber trees. Other species provide non-timber forest products that are potentially tradable outside Sudan, particularly in African countries that have over-exploited their own forest resources.

As the carrying capacity of the western and central areas of Sudan decreases, the pressure on the natural resources of the higher rainfall southern areas will increase. This in itself might initiate conflicts, as various tribes compete over a relatively rich resource base. The recent peace established between the north and south could result in depletion of the forest resources of the south through commercial exploitation.

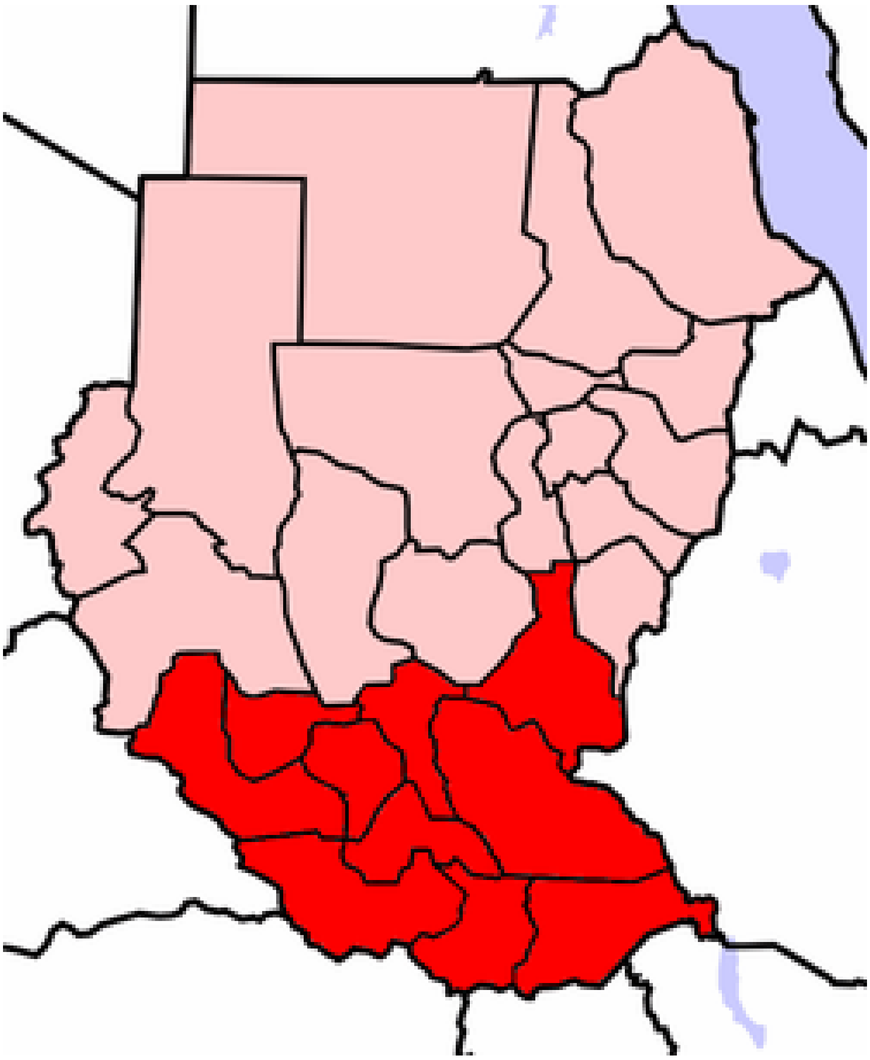


Figure (3.1) Location of South Sudan States

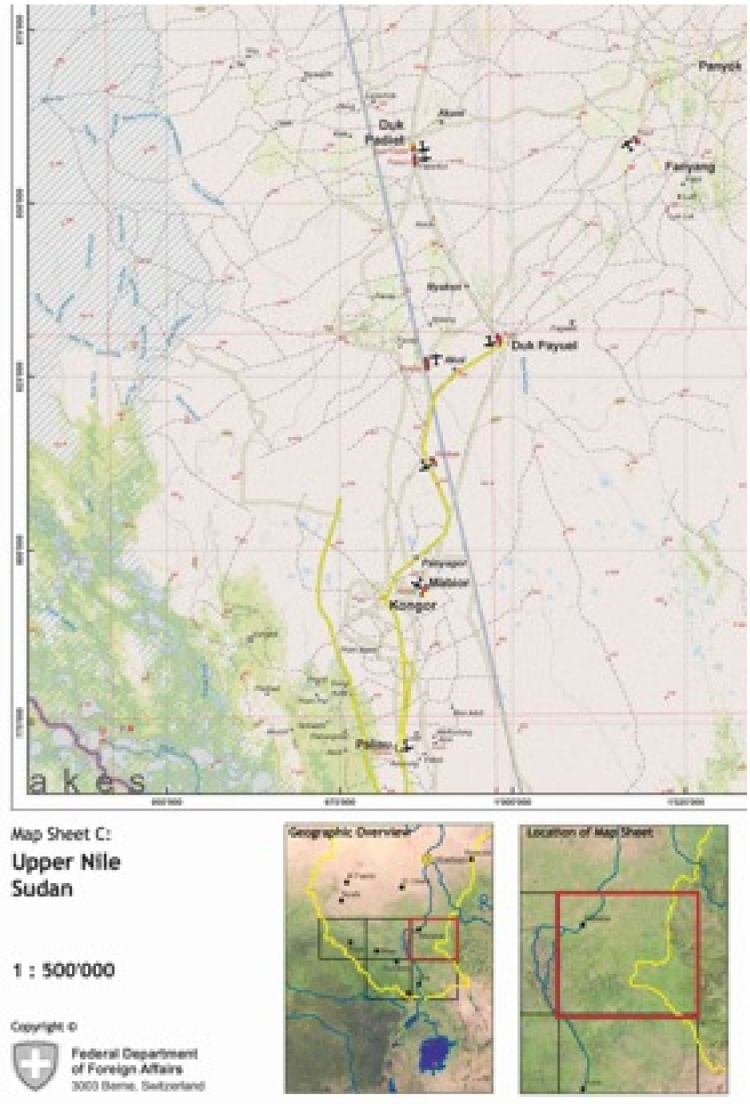


Figure (3.2) Location Upper Nile state

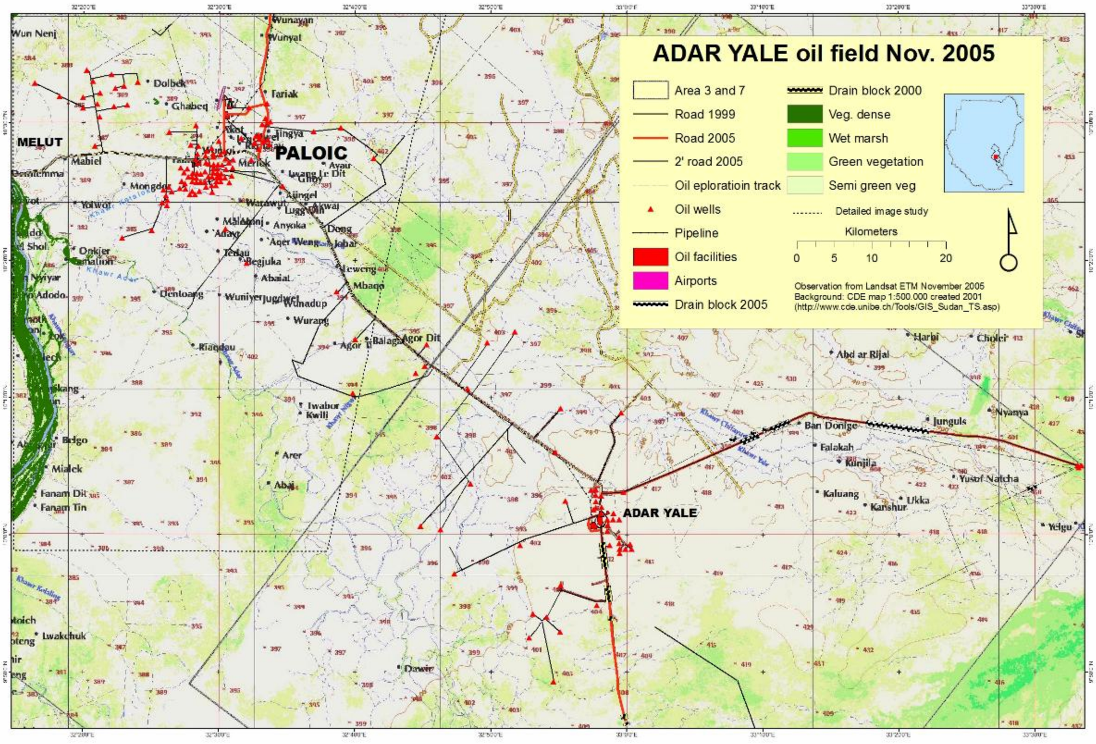


Figure (3.3) Location of study area (Paloich and Adar yale) .

3.3 Climate

The study area falls in a semi-humid tropical climate. The main feature controlling the climate of this area among other things is the Inter Tropical Convergences Zone (ITCZ) that migrates north/south across this area following apparent movement of sun (Guzman, *et al*. 2002)

3.3.1 Temperature

The mean maximum temperature over the area varies between 32ºC and 37 ºC. However, maximum temperature in the range 42-44 ºC was reported during the dry season of some years. The mean minimum temperature over the area varies between 17 ºC and 24 ºC with 9.7 ºC as the lowest temperature recorded. The daily mean temperature around the year varies between 25 ºC and 32 ºC (ibid).

3.3.2 Rainfall

Rainfall within the study area is seasonal and is connected with the movement of the ITCZ. The rainy season extends from May to October with peaks in August. The annual rainfall varies between 700mm in the northwest sector to 900mm in the southern sector of the study area with annual rainfall variability of 15-20% decreasing southwards (Figure 3.5). The period November to April is essentially dry (ibid)

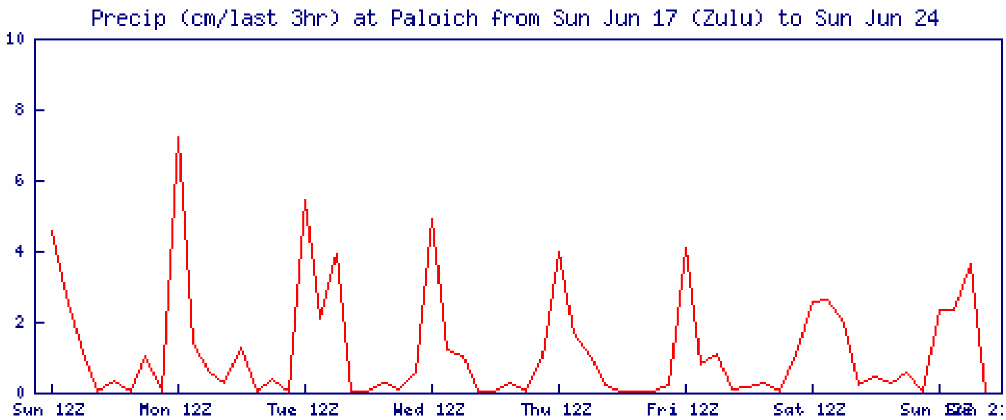


Figure (3.4) Amount of rainfall at study area (Paloich and Adar yale) during june 2004

3.3.3 Winds

During the dry season November/April, the prevailing winds are from the north/northeast, while during the wet season the winds are predominantly from south/southwest. These wind patterns reflect the shift in the surface air circulation as the ITCZ passes over the area (ibid)

3.3.4 Humidity and Evaporation

The relative humidity during the dry season varies between 20% and 40% while during the wet season it varies between 50% and 80%.

The daily mean evaporation during dry season is about 5-7 mm/day then it drops to about 2-4 mm/day during the wet season (ibid).

3.4 Soil

The soil type dominating the study area is dark cracking clay that contains clay exceeding 60% with Carbone crystals and concretions in the lower horizons. This clay soil on drying out shrinks considerably and network of wide deep cracks result. During the rainy season water penetrates through the cracks, and when they close up and the soil becomes moist it becomes impermeable. Under high rainfall and sheet flow from other areas the clay soil cannot absorb all the water and consequently flooding occurs. In spite of the impeded drainage, growth of dense annual and perennial grasses is permitted. Its formation is aqua ternary alleviation and swamp sediment;

mainly consisting of expansive rich clay layer, sandy thin clay layer and sandy layer (ibid).

3.5 Population

The Southern region has been negatively affected by the (First Sudanese Civil War, 1960) and (Second Sudanese Civil War, 1983) for all but 10 years since independence in 1956, resulting in serious neglect, lack of infrastructure development, and major destruction and displacement. More than 2 million people have died, and more than 4 million are (internally displaced) or have become (refugees) as a result of the civil war and war-related impacts (El moghraby and Asim, 2006).

The Southern Sudanese predominantly practice (Christianity) particularly (Episcopal Church of the Sudan) and the (Roman Catholicism in Sudan Roman Catholic Church) or traditional indigenous beliefs. The South also contains many ethnic groups and many more languages than used in the north. The Dinka, whose population is estimated at more than 4 million, is the largest of the many black African groups of the Sudan. Other Nilotic tribes are the Shilluk and the Nuer. The Azande, and Jo Luo are 'Sudanic' tribes in the west, and the Acholi and Lotuhulive in the extreme south, extending into Uganda (ibid).

The distinctive Juba Arabic language is a widely used (lingua franca) in Southern Sudan. Yet, the language of education and government business is English language. Juba Arabic language (arabi juba) is derived mostly from the Bari tribal native tongue. The Bari Tribe is considered the heart of Juba or Juba na Bari. Furthermore, two widely used African languages are Dinka language|Thuongjang and Nuer language|Nuer. Thuongjang (Dinka) is officially and culturally active in the states of North Barh al Ghazal, West Barh al Ghazal, Lakes, Warab, Jonglei, and Abiey. Nuer is active in Unity State and Upper Nile state (ibid).

3.6 Vegetation cover

Along the Upper Nile State and Adar yale and Palioch areas where the study is carried, out many vegetation types are found for local uses, (ElAmin, 1990). Appendix 3.1 provides a list of plant species as identified by the present study.

3.7 Tree cover

The area belongs to low savanna and most of the tree species identified in the study area are presented in Appendix 3.2

3.8 Wildlife

The area is rich in wide range of wildlife that is composed of mammals, reptiles, birds and fishes.

3.9 Sudan oil operation in southern of Sudan

In recent years, a significant amount of foreign-based oil drilling has begun in Southern Sudan, raising the land's geopolitical profile abroad (Figure 3.6). The largest overseas consortium is controlled by; the People's Republic of China, with a 40% stake, Malaysia, with 30%, and India, with 25% (The Economist, 2005) Canadian-based oil company Talisman Energy Talisman withdrew operations in Sudan in 2003.

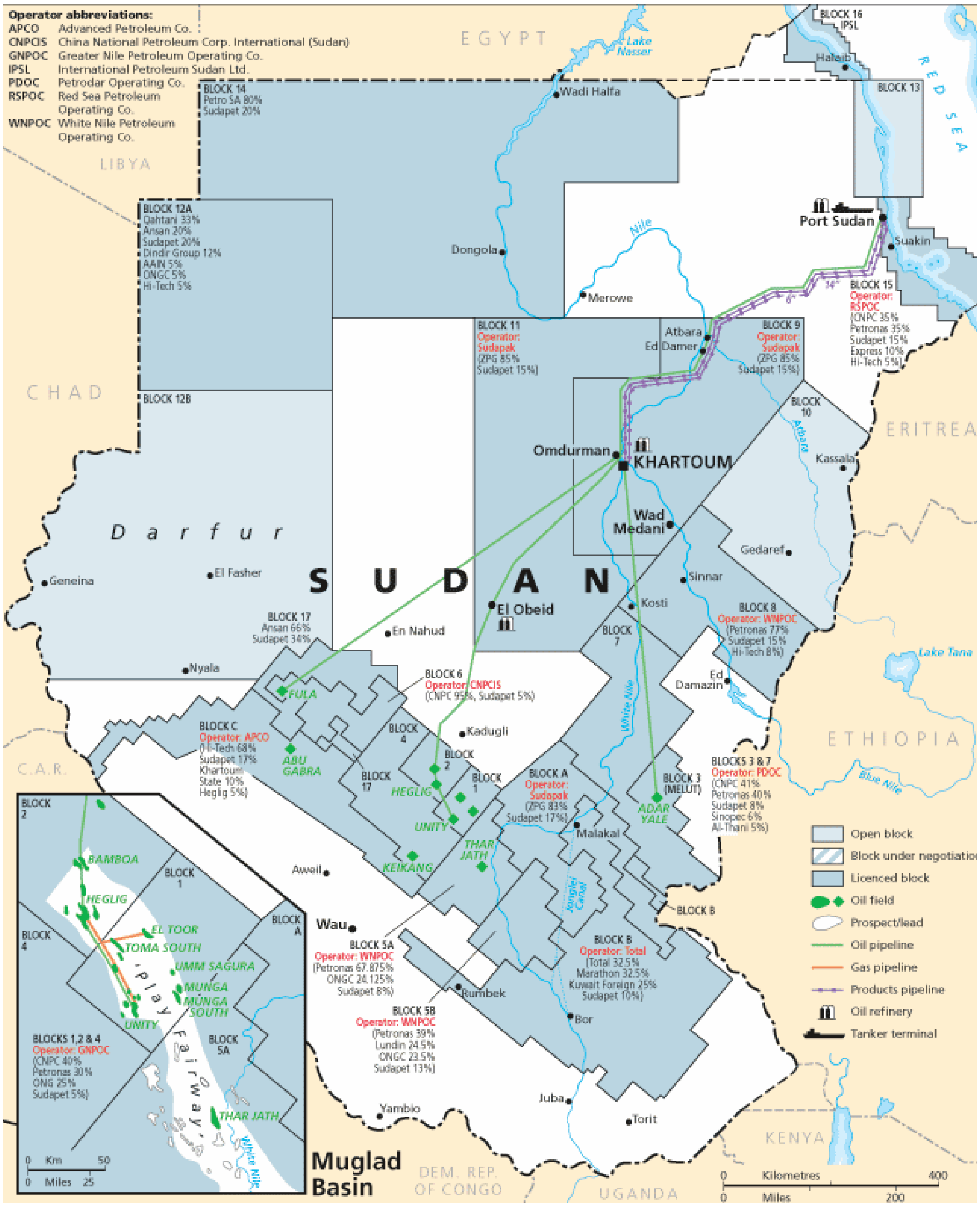


Figure (3.5) Oil field at south of Sudan where the study area of Adar yale and Paloich at the north Upper Nile State

Chapter four

Materials and Methods

4.1 General

The methodology is concerned with collection of primary and secondary data. The secondary data consists of information collected from records, reports and previous studies concerned with the study area. The source of data included south of Sudan records collected for establishment of oil industry at upper Nile State.

4.2 Land survey

Land survey was carried out in two stages. In the first stage survey was conducted based on sampling procedure conducted in December 2004 following the procedure of the national inventory 1994 (FNC, 1998). The area surveyed was determined according to the land sat 2004 data, covering an area of approximately 1.9 million hectares.

In the second stage the processing was based on the remote sensing data, of 1994 and 2004. Data of satellite imageries were analyzed qualitatively (visual interpretation) and qualitatively (information is extracted by the aid of computer). The combination of both post classification methods and spectral change detection techniques were used. The main stage of this work was presented below.

Sufficient ground control points (GPS) were used based on to verify the classification and also to observe and record the vegetation composition and land use type.

4.3 Field Data

The primary data consisted of two main sources the ground inventory data and land sat images. Within the framework of forest inventory carried in December 2004. Data was collected from Adar yale and Paloich area on natural stand of forests at the Upper Nile State. The work was based on sampling procedure using systematic line plot sampling.

4.4 Data collection

A questionnaire was conducted involving respondents from the villages and government people concerned the general description of land use area under study for categorization

4.5 Inventory

Sampling procedure was conducted based on the national forest inventory procedure conducted 1994. Systematic line plot sampling survey with fixed area circular plots of 0.1 ha was the sampling technique used. The sample plots were distributed evenly 10 Km apart along the survey line and 20Km apart between the survey lines. The radius of the circular plot was 17.84m (Elsiddig *et.al*. 2005). Grid of sample plots was prepared with the help of

GIS system, on the study area map prepared from the 2004 image. In each sample plot located by the GPS, species were recorded and for every tree (by species) the dbh was measured and recorded in cm. The crown diameters were measured in meters. The crown was projected at tangents of two diameters at right angles to each other and the average was taken in m.

Average height of each tree was obtained from two height trees that was measured. The type of land use where the sample plot falls was recorded as it falls on agricultural land, bare land or tree covered area. The procedure resulted in measurement of 190 sample plots.

The inventory data was used for two functions. It was used for land classification using crown cover percent as well as for the local definition of land use classes as taken on the basis of the questionnaire. The data was also used to calculate biomass stock by category and to use the results for assessment of biomass changes.

4.6 Selection of the satellite imagery

Two cloud free Land sat TM and ETM scenes covering the study area were obtained for the analysis. The Two images were acquired on 21/October 1994 (Figure 4.1) and 18/November 2004 (Figure 4.2). The TM and ETM data have been acquired simultaneously in seven and nine spectral bands respectively. The characteristics of TM and ETM band are suitable for detecting and monitoring the biotic as well as the non – biotic types of natural resources. According to Lillesand and Kaifer (2000), as well as Campbell (1996) TM band 1 is useful for soil vegetation. TM band 2 detects green reflectance for healthy vegetation and band 3 is designed for detection of chlorophyll absorption in vegetation.

4.7 Remote sensing image analysis

In order to assess the land use changes in the study area, two procedures of image preparation are generally employed. These are presented in the following sections.

4.8 Digital image processing

A digital image is a sampled quantized numeric representation of the scenes. In remote sensing, digital image processing historically stems from two principal application areas, the improvement of the information for human interpretation and the processing of image data for computer assisted interpretation. The whole task of digital image processing revolves around increasing spectral seperability of the objects on the image. Accordingly, the task was performed using two images (1994, 2004).

Figure 4.1 Satellite image for study area of Paloich and Adar yale, 1994

Figure 4.2 Satellite Image for study area Palioch and Adar Yale, 2004

4.9 Image enhancement

Image enhancement is the procedure applied to image data in order to more effectively display or record the data for subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in the scene. Accordingly, the spectral enhancement has been performed on both images of 1994 and 2004. Throughout most of the classification and interpretation steps, an RGB combination has been utilized frequently. It means that the band composite image with band, 4 (N- IR) with green and band 7 (red) with blue color have been developed.

4.10 Information extraction

The aim of this procedure is to utilize the decision on digital spectral and (or) texture signatures. Information extracted from the two satellite images involved image classification.

4.11 Images classification

The overall objective of images classification procedure is to categorize all pixels in an image into land cover classes or themes. Usually each pixel is treated as an individual unit composed of values in several spectral bands. Thus, the classification requirement is the multi-spectral data and spectral pattern for each pixel as numerical basis for categorization. Remote sensing image data may be classified either supervised or unsupervised classification. The study used the supervised classification with combination of three bands (band 5, 4 and 3) and supervised selected training samples, respectively.

Pixels of these training samples provide spectral characteristic for the supervised classification of the whole image. The classification provides numerical interpretation key that describes the spectral attributes for each feature in the AOI (Area of interest).

The spectral qualities of pixels in data set are the numerically compared to each category and labeled with name of land cover. Accordingly, land cover classified to five classes characterizes the vegetation cover related in the study area. The classes include vegetated and non-vegetated areas.

4.12 Change detection analysis

There are many well developed techniques for land cover change detection using the digital remotely sensed imagery. The nature of digital data allows greater comparison.

Change detection analysis approaches can be broadly divided into either post classification change methods or pre-classification spectral. In this study the two approaches of change detection were applied. Firstly, before applying any of these methods, the images from two dates are compared visually on screen and spectral signatures were selected respectively. Various color band combination and spectral enhancement methods were applied to highlight land cover types of interest. The function available in ERADS provides a possibility of this visual analysis.

4.13 The Post-classification comparison

Post classification caparison is a simple way of discriminating changes between two dates of imagery. It is common application in land cover change analysis using bi- temporal imageries of the same region of interest. After the classification of the two images by visual interpretation, two masked images have been formed. The capability of software LIWIS permits the cross classification of the two images. In the new image the change was depicted and thus unchanged pixels have been created. The output is presented within the cross tabulation matrix that explains the distribution of image pixels between the classes. Regarding this matrix, the X-axis displayed the classes of year 1994, while in the Y-axis, the classes of year 2004 were displayed.

The pixels corresponding to stable areas appeared in the diagonal entries of the matrix. Off-diagonal points of the matrix indicate areas that have changed to other land cover classes.

4.14 The questionnaire

The questionnaire was a simple from containing sets of few questions directed toward old people and officials. The questionnaire facilitated identification of land cover categories as defined qualitatively by the local communities and officials. Appendix (3.5).

CHAPTER FIVE

Results and discussion

5.1 Introduction to Remote Sensing results

Singh (1994) described change detection as a process which observes the differences of an object or phenomenon at different times. This means that it is a useful technique in detection of the change dynamics of land features. From this view point this study developed a procedure for assessment and evaluation of land use/land cover of approximately 1.92 million hectares of forest settlement for the period 1994 - 2004.

The change detection assessment was based on special statistics generated from supervised classification of spatial and temporal data using images for ETM 1994, TM 2004. Furthermore pixel-by-pixel image comparison and "cross- tabulation matrix" algorithms of ERDAS IMAGING software package were used as post-classification tools to verify the change process. The process was found to be objective and efficient in classification of the land use, land category and their monitoring in their dynamic changes.

5.2 Classification of the study area

The study area was classified during the field work into five classes used for describing the land use. The classes, named as closed forest, open woodland, scattered trees and shrubs, agriculture land and bare land. The concept of forest as defined in (FAO) 1990, included closed and woodlands and part of fragmented forests.

It is sometimes implicit, that the definition of forest determines the definition of deforestation. Since there is no single definition of forest satisfying all purposes, and in order to highlight the relativity of the concept of forest, three groupings have been used in the present survey and three forest cover categories have been defined. Classification was made according to crown cover expressed as the tree shade area as percentage of hectare area, (FAO 1990, 2000, 2005). Table (5.1) provides three levels of forest cover based on FAO (1990) system.

Table (5-1) classification of study area and density

Classes name	Tree number per ha	Density (closure %)
Closed forest	130	65.31%
Open woodland	70	14.33%
Scattered trees and shrubs	40	3.46%

5.3 Change of agricultural land matrix along the study area

Land use / land cover of Adar yale and Paloich forest settlements has been detected based on the statistical findings of the supervised classification of bi-temporal imagery (ETM 1994, TM 2004). The total area of coverage data was 1918220 ha for the ETM 1994 and TM 2004 classified into categories by area (Table 5.2).

The principal output of the remote sensing survey was a change matrix that illustrated and quantified the forest and landscape changes over time. The forest and land cover classification scheme of the remote sensing survey was linked closely to the FRA classes conducted for the national reporting as addressed for FRA 2005.

Table (5.2) shows the five forest cover classes as detected in1984 and 2004 together with analysis of change values. By comparing the classification output of the two images, table (5.2) provides land use classes changes over the period 1994 to 2004. While close forest area equal to138556.6 ha in 1994, results in 2004 shows that the area was decreased to 82075.05 ha.

Table (5-2) Net change for each category in relation to category area and total area under study

years / class	Area in 2004 (ha)	Area in1994 (ha)	Change in ten years (ha)	% of category's area	% of total area
Closed forest category	82075.05	138556.6	56481.55	40.7%	4.3%
Open woodland category	510045.9	389862.8	120183.1	30.8%	6.6%
Scattered trees and shrubs category	519683.2	591816.8	72133.6-	12.2%	3.8%
Agricultural land	582900.5	557469	25431.5	4.6%	1.3%
Bare land	223514.9	240514.3	16999.4-	3.1%	0.9%
Total	1918220	1918220			

Open woodland area was increased from 389862.8 ha in (1994) to 510045.9 ha (2004) woodland increase was 120183.1 ha equivalent to (30.8%) from category area and 6.6% from total area , scattered trees and shrubs area was decreased from 591816.8 ha (1994) to 519683.2 ha (2004) equivalent to 12.2% from category area and 3.8% from total area under study, agriculture area was increased from 557469 ha (1994) to 582900.5 ha (2004) equivalent to 4.6% from category area and 1.3% from total area under study. Bare land area was decreased from 240514.3 ha (1994) to 223514.9 ha (2004) equivalent to 3.1 % from category area and 0.9% from total area under study.

Table (5.3) shows details of the dynamic changes and area exchanges between the four land uses categories expressed as area in hectares. Table (5.3) expresses the area gained per category over ten years between 1994 and 2004.

Table 5.3 Classification of ETM 1994, TM 2004 Land cover / Land use in the study area by (Ha)

2004 / 1994	closed forest cover	woodland cover	Trees and shrubs	agricultural lands	Bare land	Total (ha)
Closed forest category	**7753.45**	27092.28	26871.23	16211.12	4146.97	82075.05
Open woodland category	30450.34	**131146.2**	186491.2	123586.3	38371.76	510045.9
Scattered trees and shrubs category	44622.34	102770.3	**161183.4**	124417.8	86689.23	519683.2
Agricultural land s	44333.83	103869.6	171372.5	**191835.5**	71489.12	582900.5
Bare land	11396.67	24984.45	45898.34	101418.2	**39817.23**	223514.9
Total by ha	138556.6	389862.8	591816.8	557469	240514.3	1918220

Each land use category is represented by a vertical column representing the data for 1994, while a horizontal row at right angle to the column represents the data for 2004 (Table 5.3). At the bottom of the vertical column is the total land area for the respective category registered in 1994. Each cell along the column indicates the value of the area lost from that category and that is gained by the other category at the left end of the horizontal row. The shaded cell indicates the end of the ten years (Table

5.3). From this shaded cell, the horizontal row shows the dynamic changes per the respective category that resulted in gains of land over ten years. At the right hand side of the row, the total land area of the category obtained by 2004.

5.3.1 Closed forest category

Taking the case of the closed forest category, the value of the area that remained as closed forest by 2004, i.e. unchanged, and was only 7753 ha out the total area of the closed forest which was equal to 138556.6 ha. This is only 5.6% of the closed forest area remained representing age-class an over the ten years. That means the closed forest lost an area equal to (138556.6 -7753.45= 130803.6) ha during the ten years period between 1994 and 2004, in a process of deforestation lost due to forest degradation. The forest area lost from the category "closed forest" represents 94.4%. The 130803.6 ha lost from the closed forest was distributed over the other four categories as gained land for the corresponding category as proceeding vertically along the column, representing the closed forest category (Table 5.3).

While the closed forest category was losing that large area of 130803.6 ha (94.4%) over ten years, it was also gaining land that was from the other categories during the same ten years period. By the year 2004, the closed forest area was 82075.1 ha gaining 74322.1 ha (53%) through a reforestation and rehabilitation processes. The 743322.1 ha gained by the closed forest category was from the loss from the other four categories along the horizontal row (table 5.3).

What was gained from the woodland category and the trees and shrubs was a rehabilitation process that resulted in increasing density in these two categories to develop into closed forest cover. What was gained from agricultural land and bare land was a reforestation resulting from regeneration process over period between 1994 and 2004.

The loss in area of closed forest resulting from forest degradation was equivalent to (4462.0 + 30450 = 75072 ha), equivalent to 54.2% of the total area of the closed forest measured in 1994. Collectively, the loss in closed forest area equal 98.4% of the total area of closed forest measured in 1994.

The loss in closed forest area represented both the deforestation process of forest conversion to agricultural land or bare land and forest degradation resulting from selective logging that decreased the cover. Deforestation in this case was equivalent to (11396.0 + 44333.0 = 55729.0 ha), equivalent to 44.2% of the total area of closed forest measured in 1994.

The difference between the total areas of closed forest measured in that measured in 1994- 2004 represents the net loss in closed forest area. This difference was abounded as (13855606 – 82075.1 = 56481.5). Expressed in relative term in relation to total area of closed forest in 1994, it is equal to 40.8% from closed forest area and 4.3% from total area under study.

The loss in area of closed forest resulting from forest degradation was equivalent to (44622.0 + 30450 = 75072 ha) equivalent to 54.2% of the total area of closed forest measured in 1994. Collectively, the loss in closed forest area equal 98.4% of total area of closed forest measured in 1994.

The factors that cause loss are the factors that enhance deforestation and degradation. The factors that enhance the gain are those constituting the potential for regeneration. Knowing the factors in both directions is important in order to enhance regeneration and control the factors that enhance deforestation.

Figure 5.1 is a breakdown of the total area lost from the category closed forest and shows the transfer of each broken part to any of the other categories expressed in percent of the total area of the closed forest recorded in 1994. Each broken unit was lost over the period 1994 to 2004. The part represented by 6% is the area remaining as closed forest measured in 2004, as to be equal to 7753.0 hectares.

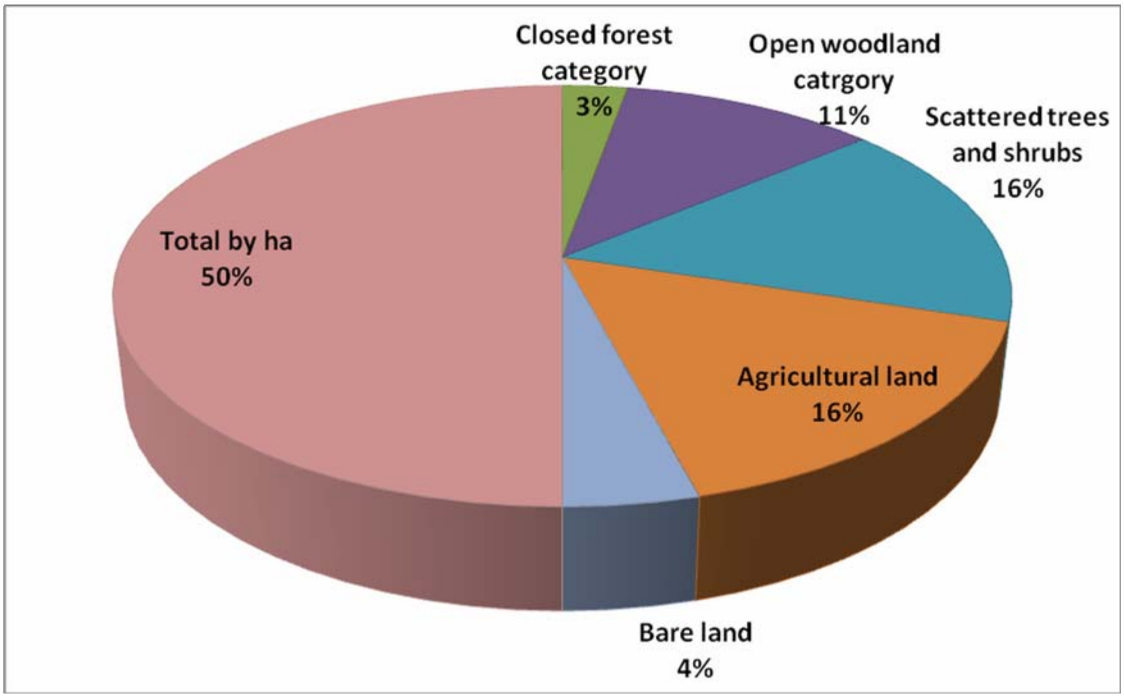
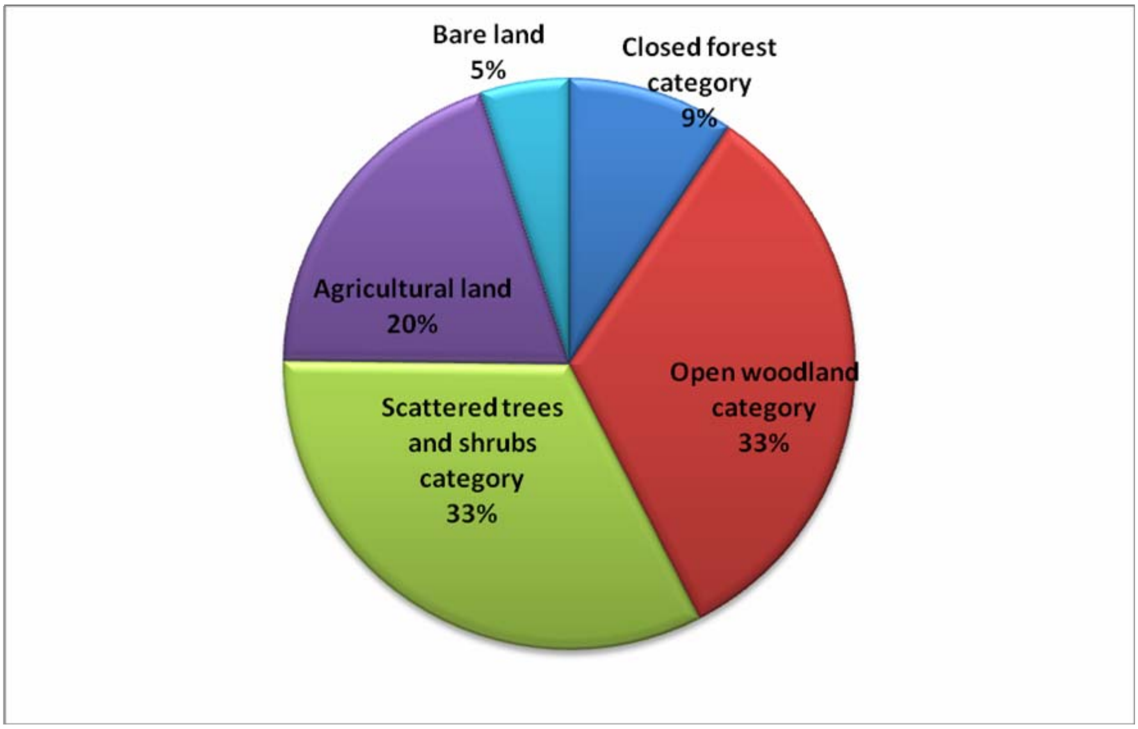


Figure (5-1) loss of forest area from closed forest category

Figure 5.2 is a breakdown of the total area gained by the “closed forest category”. The area that was found to have remained as closed forest, the 7753.0 ha equal to 6% of the closed forest area in 1994 was the same area considered as part of the closed forest standing in 2004. In the latter case the 7753.0 hectare will be 9.4% of the area of closed forest measured in 2004. The other parts of the forest area of closed forest were gained from other categories as shown by Figurer 5.2.



Figurer (5-2) Gained area to closed forest from other categories

5.3.2 Open Woodland Category

The process of cover changes associated with any of the other categories followed similar sequence as in the case of closed forests discussed under section (5.3.1). The value of the area that remained as open woodland by 2004 ,i.e unchanged was (131140) ha while the total area of the category recorded in 1994 was (38962.8) ha during ten years between 1994 to 2004 ,indicating a total loss of (258722.8) ha equivalent to 66.4% of the total area of open woodland category detected in 1994. As in the case of closed forests, the loss was caused by deforestation resulting from conversion of (103869.0) ha into agricultural land (Table 5.3) and conversion of (2498.0) ha into bare land .These two figures of forest clearance is equivalent to 33.1% of the total area of woodland category, as deforestation area.

Another part of the loss was caused by forest degradation caused by selection logging within an area of (102770 ha) changed to trees and shrubs equivalent to 26.4% of the area of open woodland, (Table 5.3). However, part of the change of open woodland represents an improvement and development of (270922) ha of the woodland into closed forest equivalent to 7.0% of the total area of the woodland.

The open woodland was also gaining additional land as a result of change from other categories into open woodland. Proceeding from left to right along the horizontal row defined by open woodland (Table 5.3), the category gained 30450.0 ha, equivalent to (7.8%) from closed forest category which is a result of forest degradation and (186492.0) ha equivalent to (47.8%) from trees and shrubs category which is a result of rehabilitation process . The category also gained 123580.0 ha, equivalent to 31.7 % from agricultural land category and 38371.0 ha, equivalent to 10.0 % from bare land category, resulting from reforestation.

Total land area gained by the open woodland was (379336.3) ha equivalent to (97.3%) while the total loss was (66.4%) of the woodland area.

Accordingly the resulting net gain was (32.9%) of the total area of the woodland detected in 1994.

Figure (5.3) provides the total forest loss from the open woodland category transferred to the other land use categories expressed in percent of the total land area of the open woodland category measured in 1994

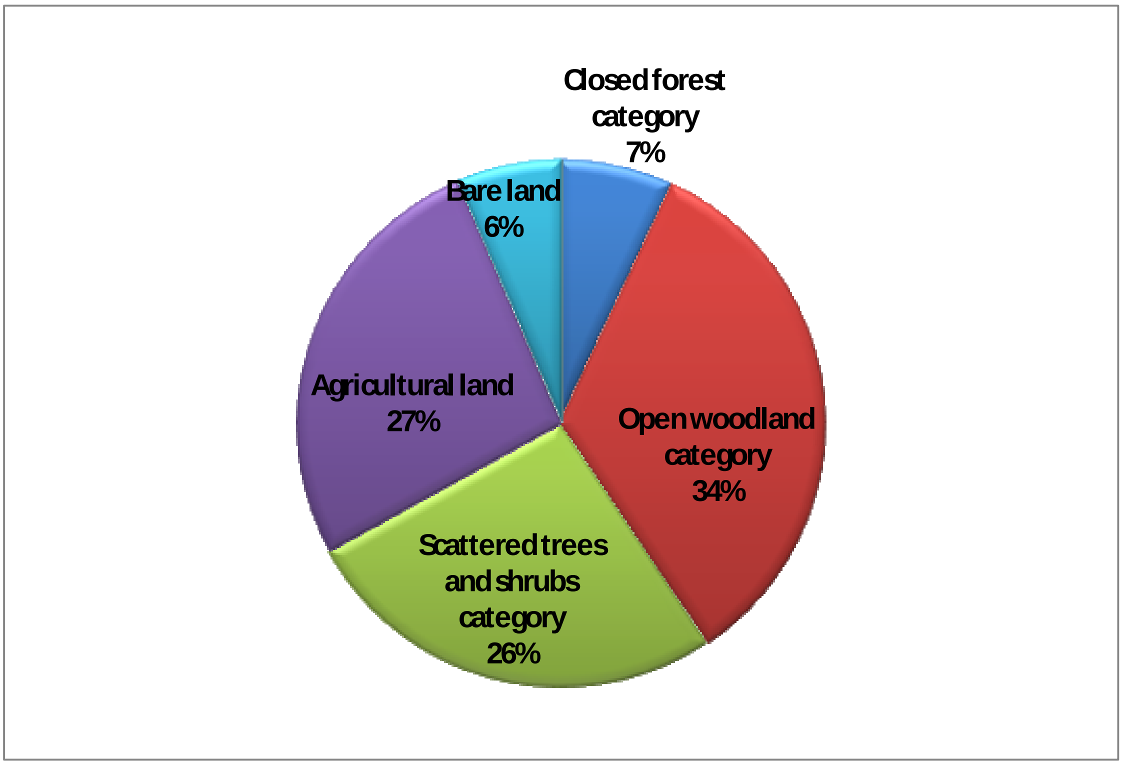


Figure (5.3) Loss of forest land from open woodland category

Figure 5.4 indicates the total area gained by the open woodland category taken from other categories and expressed in percent of total area of the open woodland category measured in 2004.

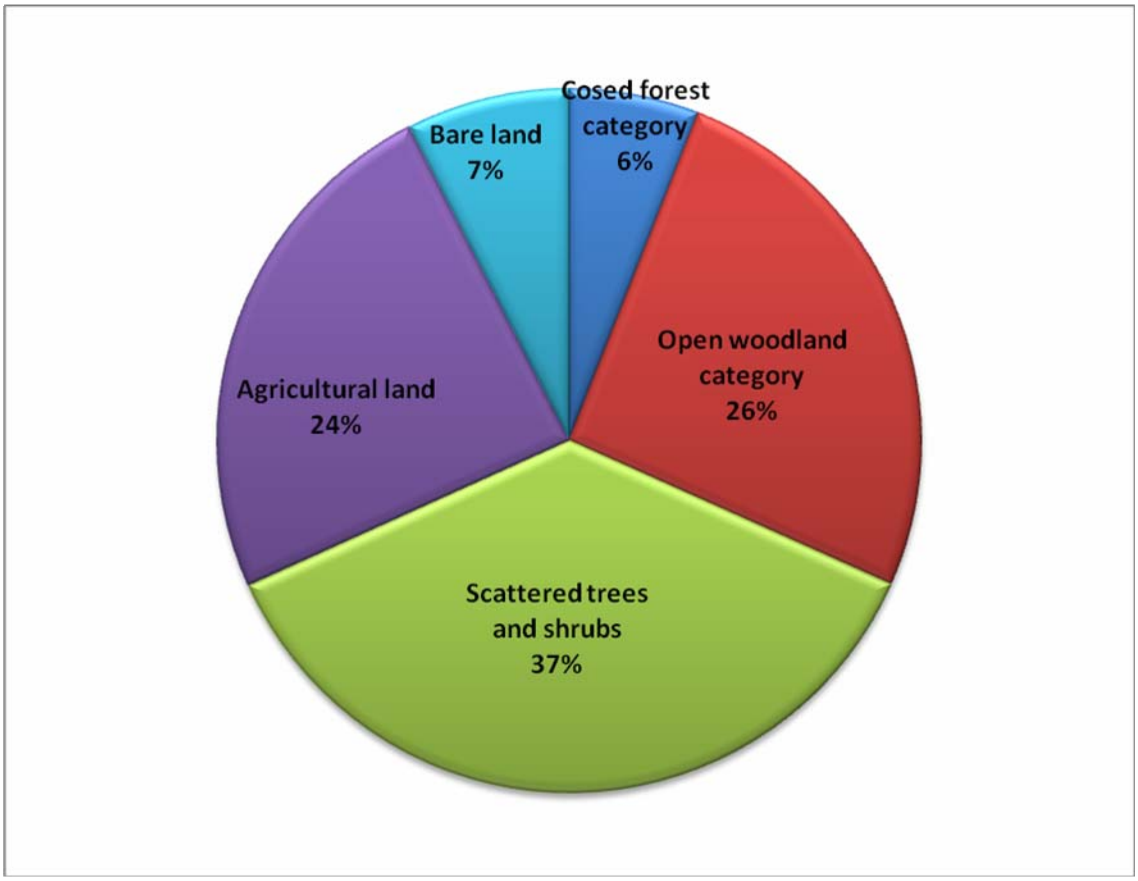


Figure (5.4) Gain of forest land to open woodland category

5.3.3 Scattered Trees and shrubs category

Scattered trees and shrubs category represents a land use system which have trees on land that have crown cover less than 10% and accordingly is not defined a forest. Increased density and crown cover leads to improving the tree cover into woodland or closed forest categories. This process is based on tree regeneration and forest rehabilitation. On the other hand, cutting of trees leads to conversion of scattered trees and shrubs category into agricultural land category or bare land category process which result in deforestation. Both processes of rehabilitation and deforestation in association with scattered trees and shrubs category were experienced in Adar yale and Paloich area.

As a result of these processes, the scattered trees and shrubs land area was changed during the ten years 1994-2004 and by the year 2004 the part of the scattered trees and shrubs remained unchanged was only (16118.0) ha equivalent to (27.3%) out of (591818.8) ha the total area of the category.

The total loss of scattered trees and shrubs area was (72.7%) of which (45898) ha equivalent to (7.7%) lost as bare land and (171372) ha equivalent to (29%) lost as agricultural land. These two types of losses took place a result of deforestation equivalent to (36.7%) of the area of scattered trees and shrubs category.

The other type of land loss experienced by the category scattered trees and shrubs represents rehabilitation and development of this category into forests either open woodland or closed forest resulting from reforestation process. The loss or the area taken from scattered trees and shrubs was (186490) ha equivalent (31.5%) developed into woodland category and (26871) ha equivalent to (4.5%) developed into closed forest category, together making (36.0%) of the area of the scattered trees and shrubs category, (Table 5.3).

Associated with the losses, the scattered trees and shrubs gained, during the ten years 1994-2004, lands area of (358500) ha equivalent to (60.6%) the unchanged area (16118.0) ha and the total area of scattered trees and shrubs became (519683.0) hectares.

Part of the land gain for the scattered trees and shrubs through forest degradation of closed forest (44622.0) ha equivalent to (17.4%) and woodland (102770) ha equivalent to (17.5%) resulting in 24.9% gain. The other part of the gain was added to the category by reforestation process. Of this part (124419.0) ha equivalent to (21.0%) was a change from agricultural land and (86689.0) ha equivalent to (14.6%) as a change bare land. These two types together equals to 35.6% of the area of the scattered trees and shrubs category. The total gain for the scattered trees and shrubs category was 70.5% measured in 2004.

Figure 5.5 provides the dynamic changes in relation to the scattered trees and shrubs category. It shows the direction of losses of land and its transfer to other categories, expressed as percent of total land area of scattered trees and shrubs category measured in 1994.

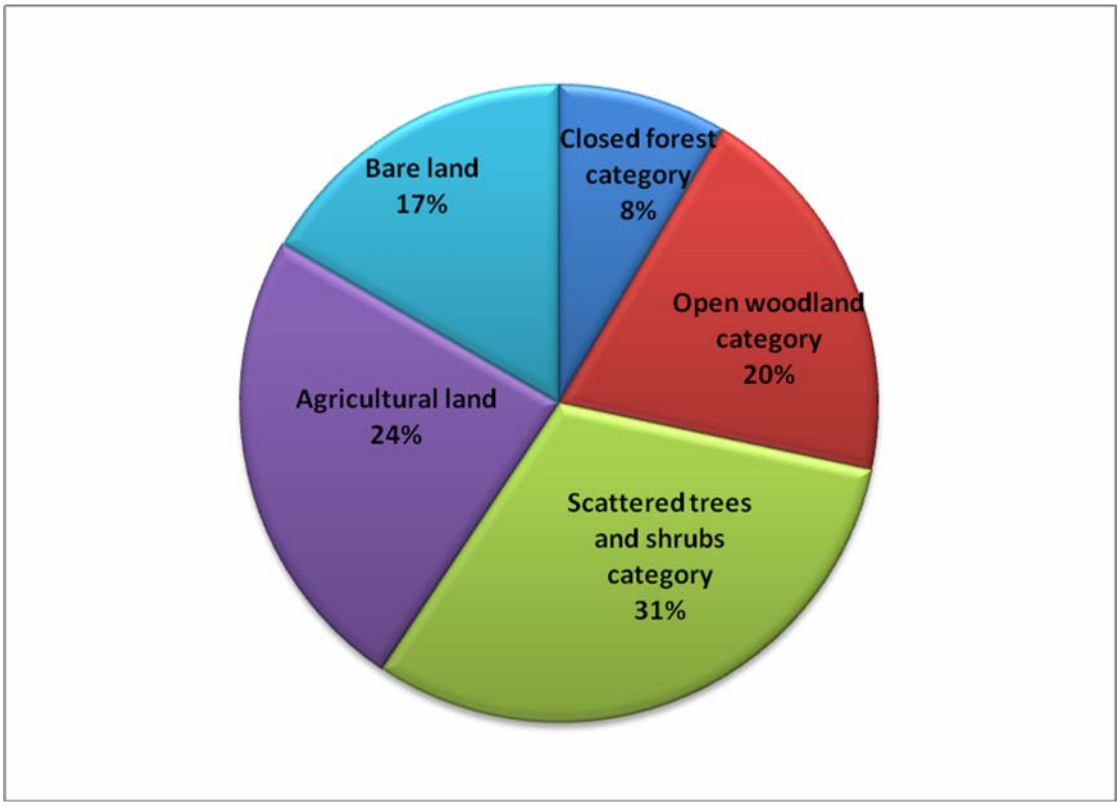


Figure (5.5) Loss in forest area from scattered trees and shrubs category

Figure (5.6) indicates the total area gained by the scattered trees and shrubs category taken from other categories and expressed in percent of total area of the scattered trees and shrubs category measured in 2004.

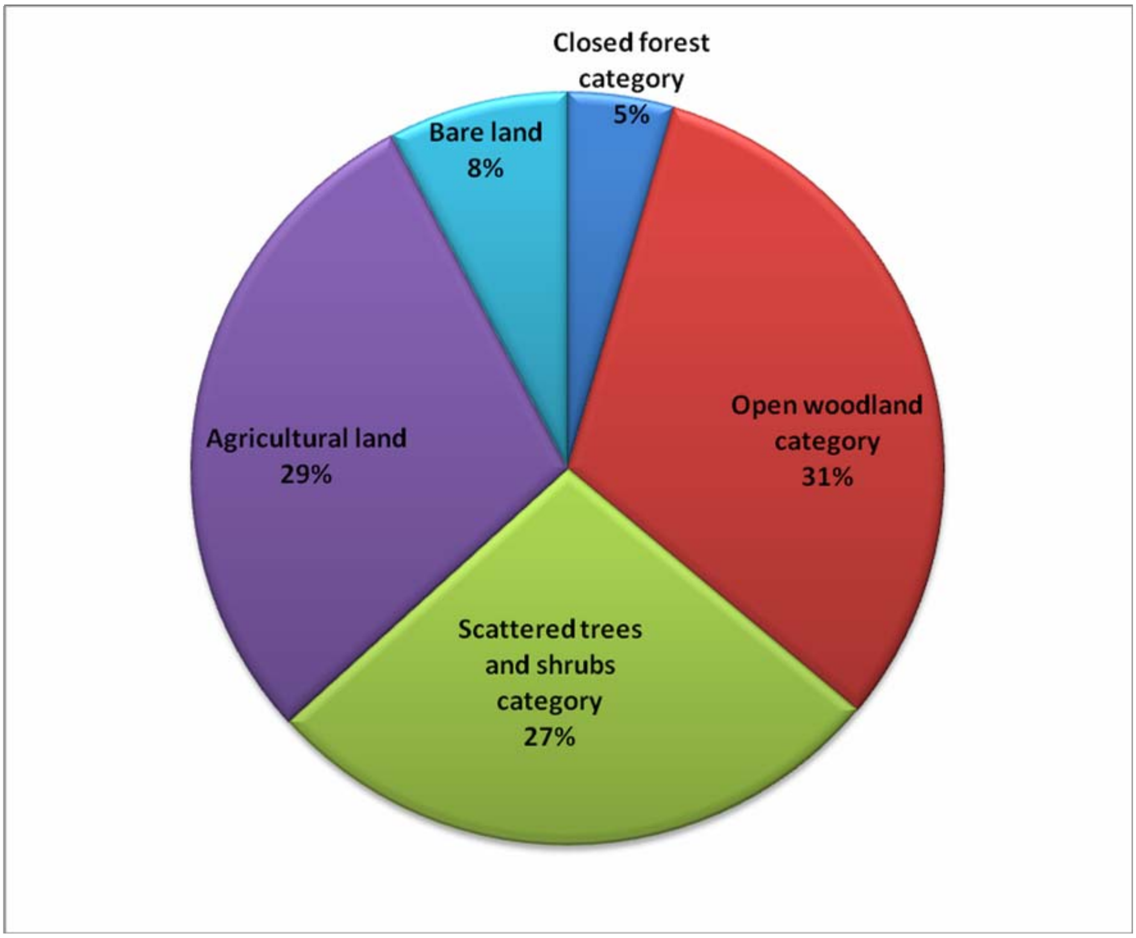


Figure (5.6) Gain in forest area to trees and shrubs category

Taking the forest land categories (closed forest, open wood land and scattered trees and shrubs) all combined as forest and tree cover, their total area in 1994 was (1120236.2) ha equivalent to (57.9%) of the total area under study. In 2004, the total area of the three categories of forest and tree cover was (1111804.1) ha equivalent to (57.96%). Closed forest is losing forest land, scattered trees and shrubs are losing forest land while open woodland category is gaining (Table 5.4).

However, the three categories have collectively lost some land, that means the forest cover declined. The area of 8432 hectares lost from the three categories are gained by the agricultural land use, and that represents the extent of deforestation, (Table 5.4).

Table 5.4 the change from forest classes to agricultural land at study area

Forest classes	Area gain 2004 (ha)	Area lost 1994 (ha)	Net of change (ha)
Closed forest	74321.6	130803.15	- 56481.55
Open woodland	103869.6	123586.2	+ 19716.7
Scattered trees and shrubs	171372.5	124417.8	- 46954.7

5.3. 4 Agricultural land Category

Agricultural land category is the dominant type of land use that represented the highest occupation of the land. In 1994 the total agricultural land was (557469) ha equivalent to (29.1%) of the total land of the study area. In 2004 the agricultural land area increased to (582900.5) ha equivalent to (30.4%) of the total study area. Agriculture was managed under shifting cultivation system that, during ten years (1994-2004) experience dynamic shifting between other categories resulting in losses in forest cover and gains of agricultural land.

Of the total area recorded as agricultural land in 1994 only (191835) ha equivalent to (10%) remained in 2004 as unchanged (Table 5.3).This area was 10% of the total area under study and only 34.4% of the total area of agricultural land recoded in 1994. Some area of agricultural land (101418.0) ha equivalent to (18.2%) of agricultural land was abandoned and left bare land in 2004 (Table 5.3).The rest of the land that went in process of changes through tree regeneration and developed into either of three categories that have trees.

Land development into trees and shrubs utilized an of area of 124419.0 ha equivalent to (22.3%) of the 1994 agricultural land to develop into trees and shrubs category. Development into woodland category covered 123580.0 ha representing (22.2%) of the agricultural land area of 1994.

The conversion of agricultural land through reforestation into the three categories that bear trees utilized a land area from agriculture equal to 247999.2 ha equals to 44.5% of the 1994 agricultural land. This development represented very large area of agricultural land into forested area. Against this area, the forested land lost some land cleared for agriculture.

Going horizontally from left to right along the row defined by agricultural land category (Table 5.3), the changes of land transferred into agriculture is observed and analyzed. Closed forests category lost 44333.0 ha into agriculture, open woodland lost 103869.0 ha into agriculture and the scattered trees and shrubs lost 171372.0 ha transferred into agriculture and together, these lands equal 319574 ha equivalent to (57.3%) of the total land area of the agricultural land registered 1994. This area represented large areas converted from forested land by deforestation process to be used for agriculture.

The deforested land area of 57.3% upset the large area of 44.5% of the agricultural land being reforested. The large area deforested 319574.0 ha exceeded the area reforested 247999.0 ha resulting in a net gain of land transferred into agricultural land 71523.3 ha equivalent 12.3% of the agricultural land recorded 1994. It is clear that there is greater area deforested and developed into agriculture than that reforested and developed into forest and tree cover.

Figure 5.7 provides the total loss from the agricultural land category transferred to the other land use categories expressed in percent of the total land area of the agricultural land category measured in 1994.

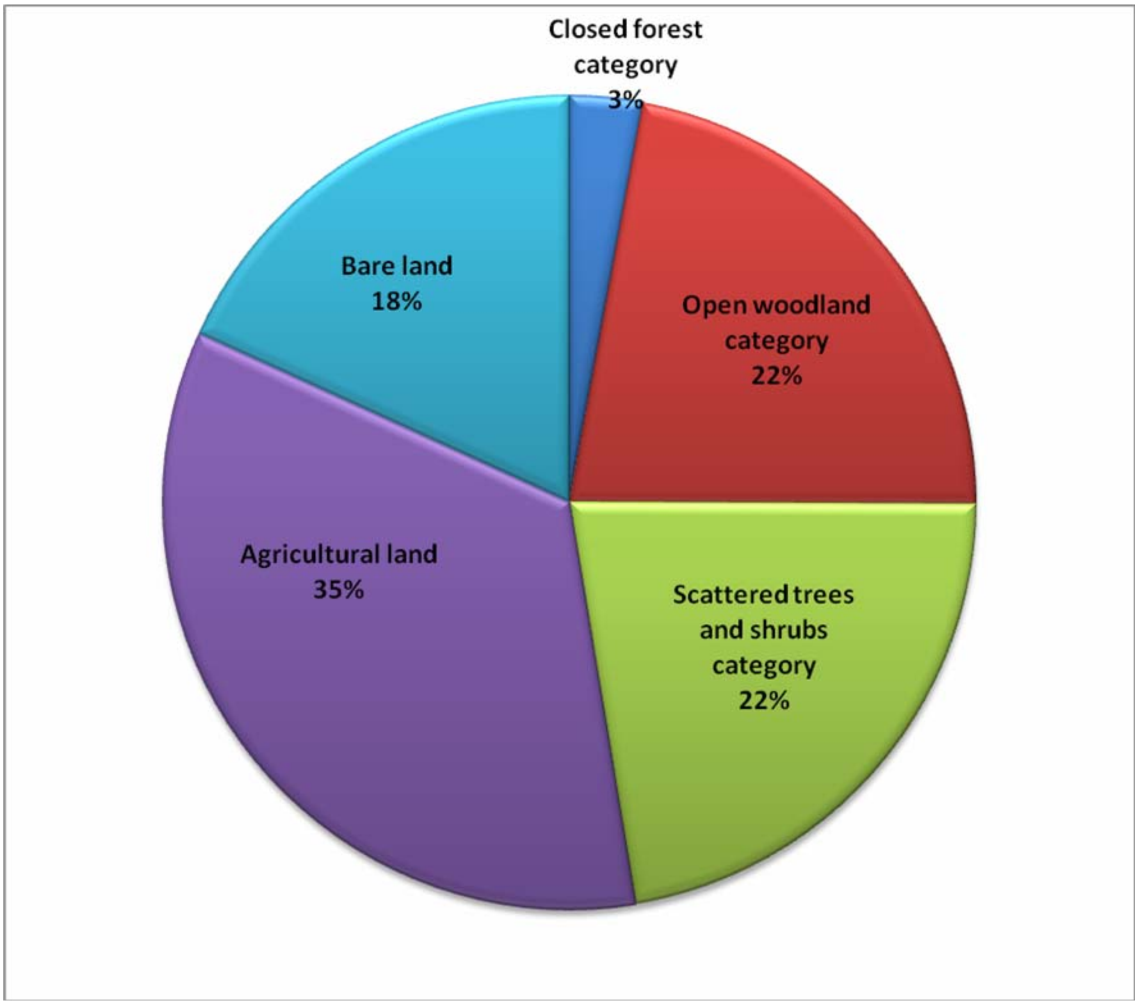


Figure (5.7) loss of land from agricultural land transferred into other categories of land

Figure 5.8 indicates the total area gained by the agricultural land category transferred from other categories and expressed in percent of total area of the agricultural land category measured in 2004.

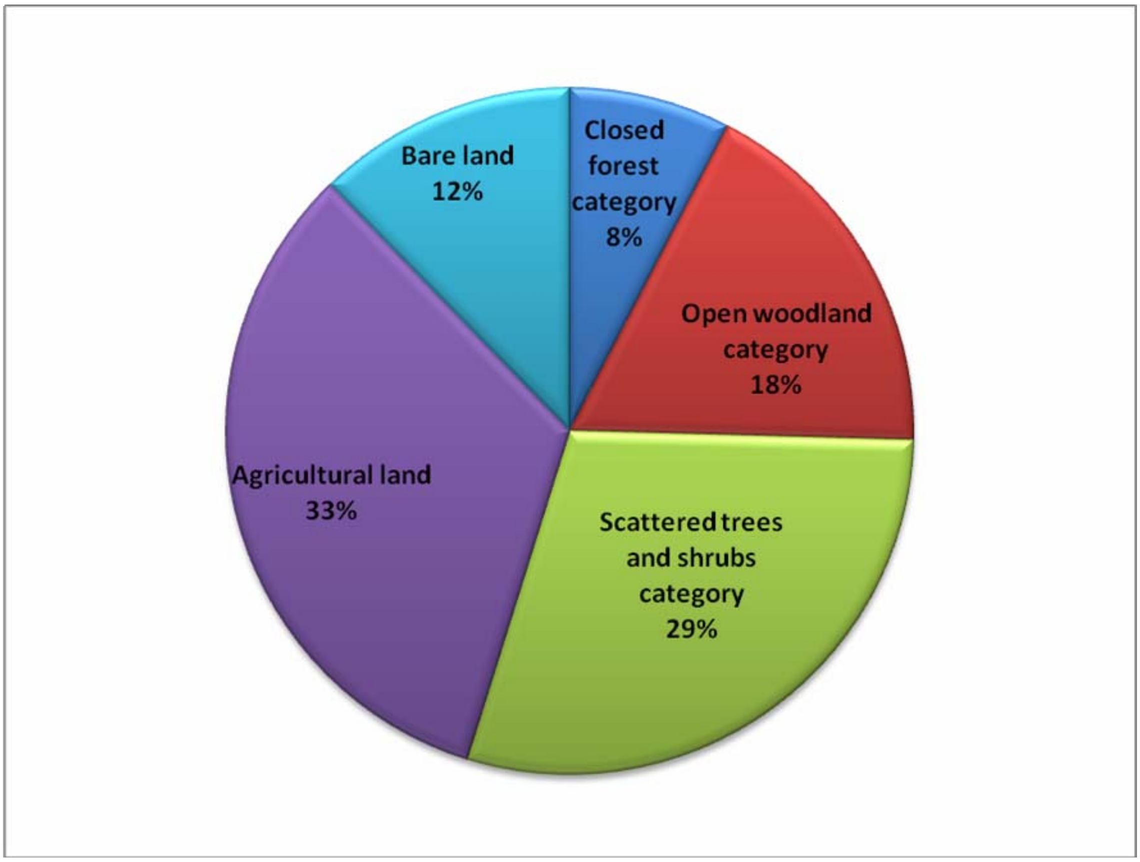


Figure (5.8) Gain to agricultural land from other categories in land transferred

5.3.5 Bare land Category

Bare land was once agricultural land, abandoned and left as fallow because of reduced productivity. The land in this category represents potential land for grazing or for agricultural use, but might also get rehabilitated through tree regeneration to developed into land covered with scattered trees and shrubs or with forest as open or closed.

The bare land area recorded in 1994 (last end of vertical Colum of bare land) was 240514.3 ha equivalent to (12.5%) of the total land of the study area. The part of this land that was unchanged by 2004, i.e remained bare land was 39817.0 ha equivalent to (16.5%) of the bare land in 1994 and equivalent to 2.1% of the total land of the study area.

That small area of 2.1% represents a good indicator of improved land use and development of the bare area into other useful land uses. In fact the major part of the bare land was developed into land covered with trees and forests.

The part converted into scattered trees and shrubs was equal to 86689.0 ha equivalent to 36.0% of bare land and that converted to woodland was 38371.0 ha equivalent to 16.0% of the bare land area and that converted to closed forest was 4146.0 ha equivalent to 1.7% of the bare land area. In total an area of 12706 ha of bare land was naturally regenerated into different levels of tree cover representing 53.7% of the bare land area registered in 1994. Such level of reforestation is an indicator of the potentialities for natural regeneration.

The part of the bare land used for agriculture was 71489 ha equivalent to 29.7% of the bare land of 1994. In total, the bare land that was used was equivalent to 83.4% of bare land and only 16.6% remained as bare. While the major part of the bare land detected in 1994 was converted to other land use types that appeared to indicate rehabilitation of bare land, other land use categories were losing part of their lands to be degraded as bare land. Closed forests lost 11396 ha equivalent to (4.7%) of the bare land, woodlands lost 24984.0 ha equal to (10.4%) of bare land and scattered trees and shrubs lost 45898.0 ha equal to (19.1%) of bare land, together equal to 34.2% of the bare land area in 1994.

The agricultural land category lost 101418.0 ha equals to 42.2% of the bare land area of 1994. Together, the area converted to bare land by 2004 was equal to 76.4% of the bare land area while the rehabilitation area was 83.4% of the bare land in 1994. The net rehabilitation land was 7.0% bringing the bare land to an area of 223514.0 ha in 2004 from an area of 240514 ha in 1994, which indicates a reduction in the bare land area.

This situation indicates that while there is potential for bare land development of the bare land into other land uses, there is also high risk of conversion of forests and agricultural land into bare land. Understanding of the causes of either of the two situations is important in order to enhance regeneration and control deforestation.

Figure 5.9 provides the total loss from the bare land category transferred to the other land use categories expressed in percent of the total land area of the bare land category measured in 1994.

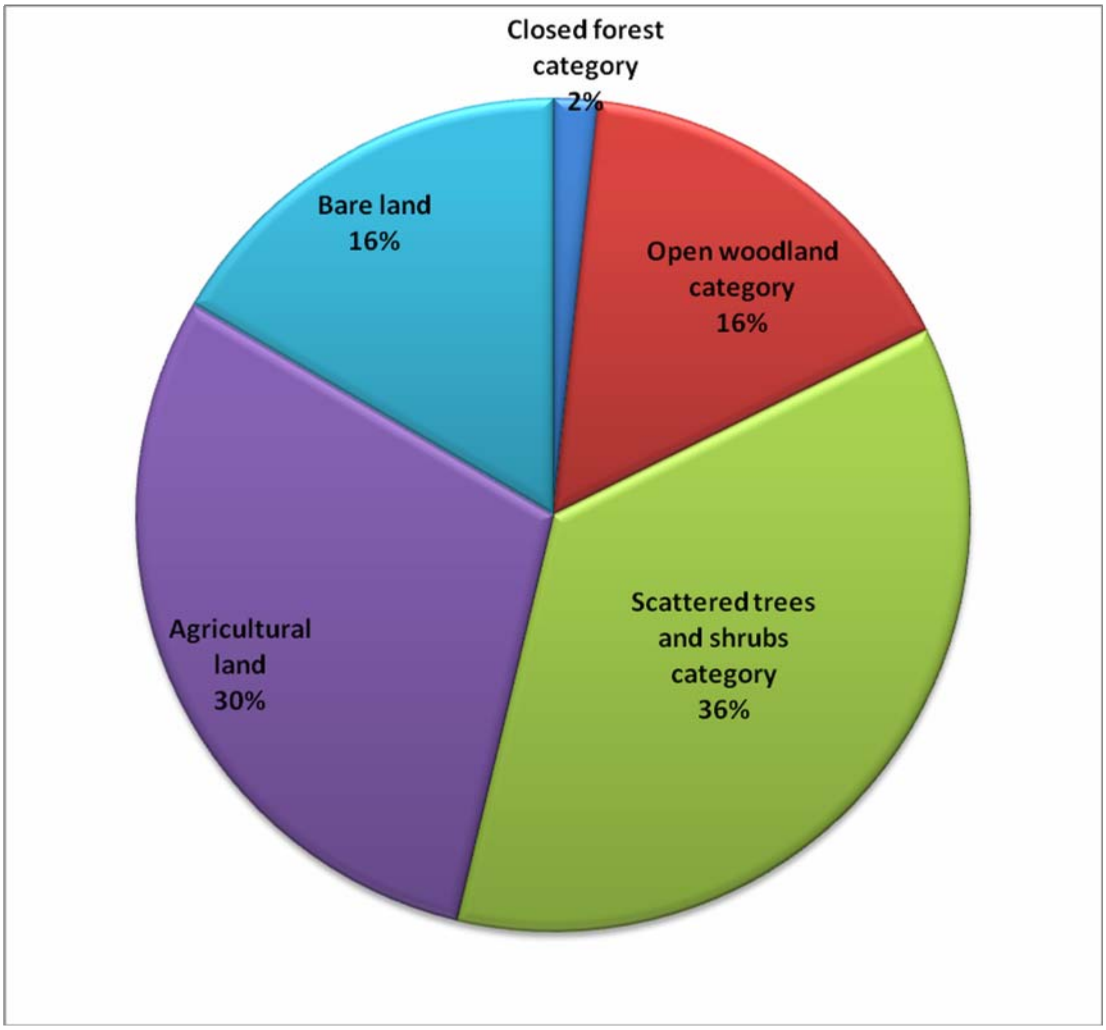


Figure (5.9) Loss in land from bare land transferred to other categories

Figure 5.10 indicates the total area gained by the bare land category taken from other categories and expressed in percent of total area of the bare land category measured in 2004.

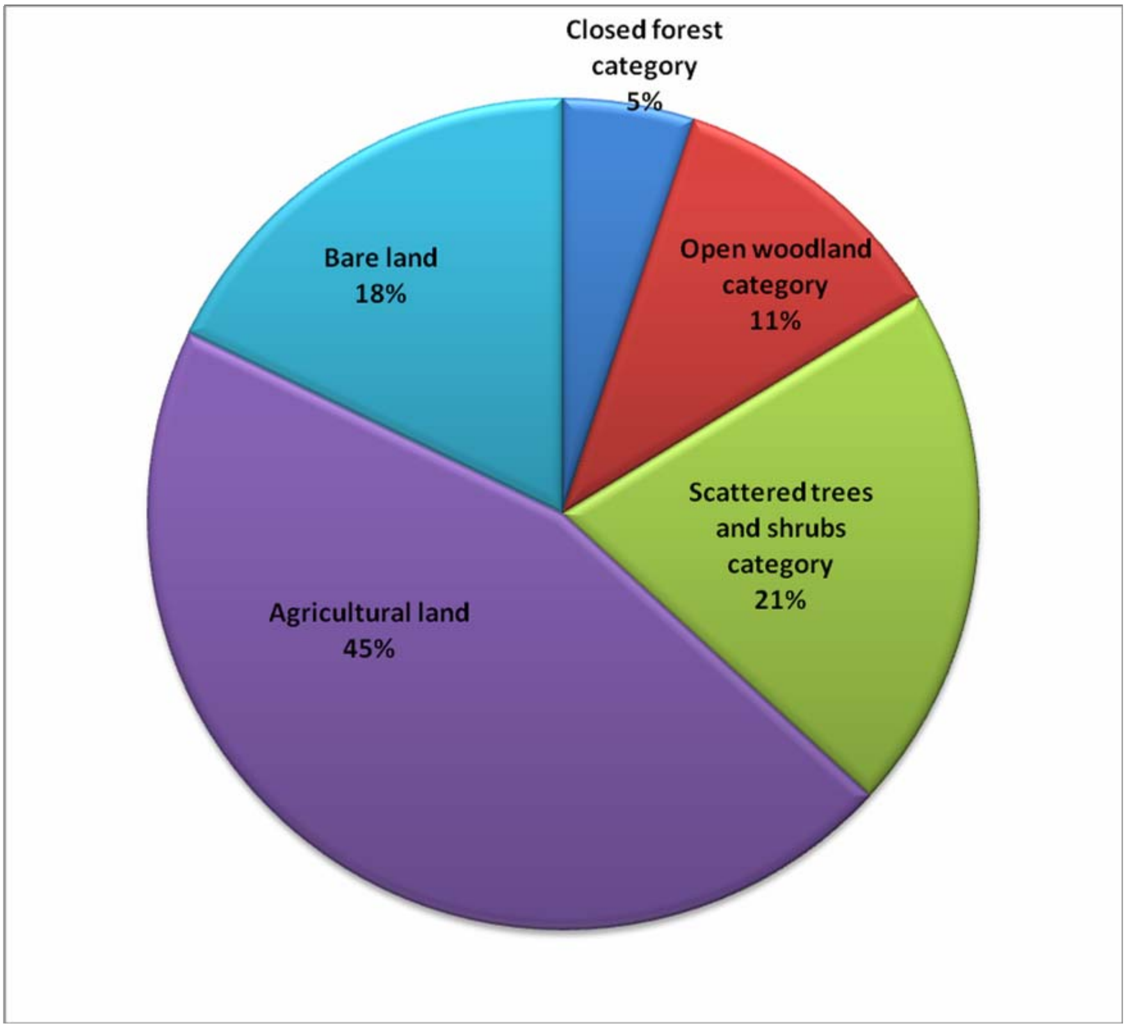


Figure (5.10) Gain to bare land transferred from other categories in land

5.4 criteria and indicators

The comparison between land use classes obtained from the classification of imagery ETM 1994 and TM 2004 indicates that land use /land cover of the study area showed marked changes during the ten years period from 1994 to 2004. Changes detected for any of the five land use categories over the specified period of time provide data of successive measurements that constitute the basis to address criteria and indicators to monitor and evaluate the extent of changes at large area level. Identification of the appropriate criteria and indicator to be addressed by successive measurements data improves the capacity to assess extent of changes and their impacts.

However, it seems necessary to use selected biological indicators to evaluate the extent of change of forest land and other land categories when displayed in maps at the specific times define in the present study at 1994 and 2004 using land sat images. The indicators used in the present study are defined by “extent of area by forest type relative to total forest area and land use area”. Observation of forest cover extent indicates that the forest cover is spatially changing from large tracts (Figure 5.11) to fragmented forest land (Figure 5.12).

The sharp decline in forest area between 1994 to 2004 and conversion of forest lands into fragments is occurred as results of some factors that caused the transfer of forest into scattered trees and shrubs, agricultural land or bare land. The impact of agriculture at development on the forests is reflected in the fragmentation and conversion of forest treats into small relics scattered over the area.

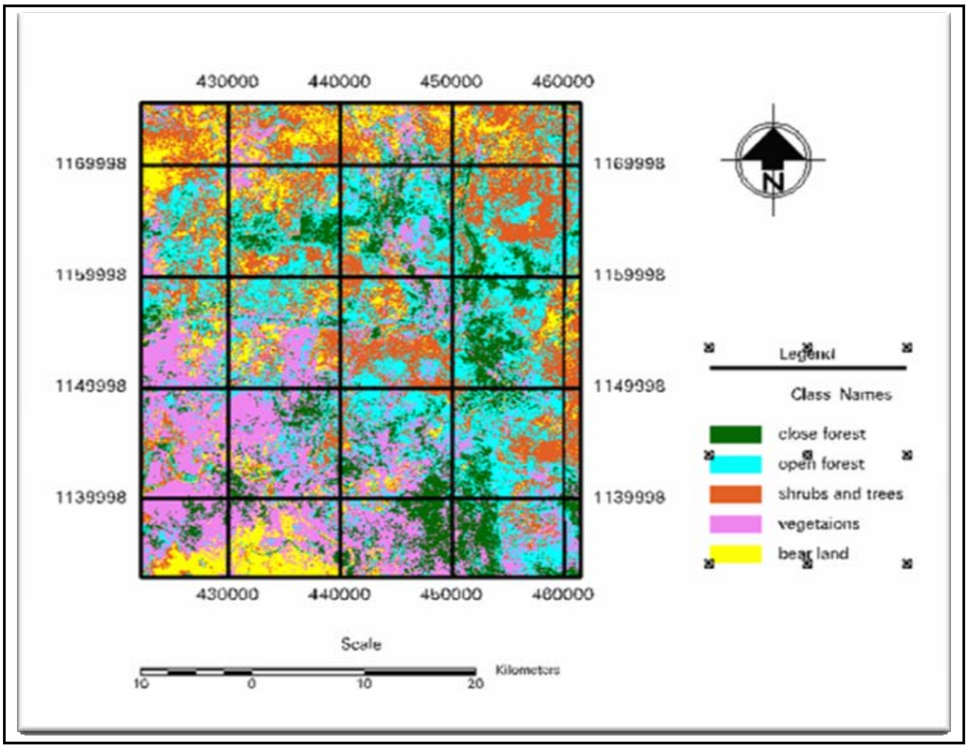


Figure (5.11) Supervised classification map of ETM Land sat data 1994

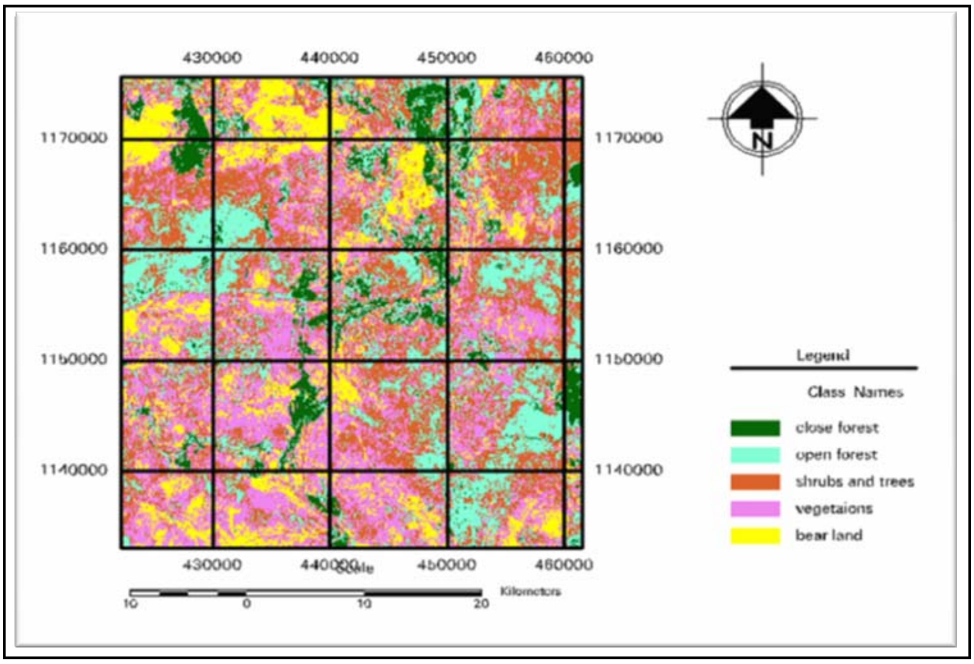


Figure (5.12) Supervised classification map of TM Land sat data 2004

The extent of forest cover measured as area in hectares is expressed in percent of total study area an indicator with regards to forest condition. (Tables 5.2 and 5.3). Criteria and indicators were established for country level reporting to facilitate development of policies that would support sustainable forest management at national level and provide frame works for monitoring and assessing trends.

Sudan was classified within the top ten countries that had great annual net loss within the world score (FRA 2005) estimated as annual net loss of forest land 589000 ha per year (Table 5.5).

Table 5.5 Assessment of Forest Resources (FRA) 2005. Ten countries with the largest annual net loss in forest area 2000 - 2005

country	Annual change (1000 ha/yr)
Brazil	- 3103
Indonesia	- 1871
Sudan	- 589
Myanmar	- 466
Zambia	- 445
United Republic of Tanzania	- 412
Nigeria	- 410
Democratic Republic of the Congo	- 319
Zimbabwe	- 313
Venezuela	- 288
Total	- 8216

Source (FRA, 2005).

Table (5.6) shows the total net changes in land use whether positive or negative between 1994 to 2004. The forest area detected between two points of time is not usually a sustainably existing forest cover. Forest is cleared while regeneration may take place. It appears that net change in land use classes varies over time as increasing or decreasing. However, it seems that analysis of land use changes over long time may show a gradual average annual change in a positive or negative change.

Table (5.6) Sudan forest cover and annual change rate FRA 2005

	Area in ha (*1000)			Annual change rate
country	2000	2005	2000-2005	percent
Sudan	76,381	70,491	-589	-0.8

Source (FRA 2005)

5.5 Accuracy Evaluation

Assessment of image classification accuracy is a measure of correctly classified pixels related to total pixels expressed in present. The assessment involves "producer accuracy" and "user accuracy" performed in a processing programme.

Results of accuracy assessment is presented in (Table 5.7) for producers accuracy and (Table 5.8) for users accuracy.

Table 5.7 Accuracy Assessment for Image classification 1994

Category	Producer Accuracy percent	User Accuracy percent	Average percent
Closed forest	94.5	97.5	96.0
Open woodland	92.7	93.3	93.0
Scattered trees and shrubs	90.5	91.5	91.0
Agriculture	86.5	84.3	85.4
Bare land	80.8	83.6	82.7

Table 5.8 Accuracy Assessment for Image classification 2004

Category	Producer Accuracy percent	User Accuracy percent	Average percent
Closed forest	97.5	98.5	98.0
Open woodland	92.8	96.4	94.6
Scattered trees and shrubs	92.6	90.4	91.5
Agriculture	89.8	87.4	88.6
Bare land	90.2	88.2	89.2

Tables 5.7 and 5.8 indicate that higher accuracy has been presented in relation to closed forests and other forest cover which it is lowest in

relation to agriculture and bare land. However the accuracy results indicate that the extent of reliability is high.

5.6. Ground survey and forest cover

Three species constitute the main dominant species in the area including:

- *Acacia seyal.*
- *Balanites aegyptiaca.*
- *Acacia Senegal*

The *Acacia seyal* is well established and distributed over the whole area but more concentrating from the east to west along the middle site of study area in wide range of size classes where found, different size in term of both dbh. and height , ranging from (15-46) cm and height (10-18) m. On the shallow flooded site seedlings were observed.

Balanites aegyptiaca exists as woodland covering the area increasing in density and size classes' south ward. The ever green feature of the trees form green canopy is characterizing the landscape. The dbh ranges between (45-89) cm and height ranges from (15-28) m.

Acaia senegal exists on recently abandoned agricultural lands and found in mixture with A.*seyal* and *Balanites aegyptiaca* in older fields. *Acacia Senegal* covers the northen part of the study area in patches and in scattered trees and open woodlands, it is represented by low percent in the closed forest category.

5.6.1 Land use category

The 190 sample plots distributed over the study area were classified by land use type, based on the number of sample plots location. The forest and tree cover of the three categories had 118 sample plots while the agricultural land and bare land revived 72 samples. Table 5.9 shows the distribution of sample plots expressed in percent of total number of sample plots classified by categories compared with the categories areas percent obtained by land sat classification.

Table 5.9 Compatibility and land classification using land sat and ground survey 2004

	Ground survey		Land sat	
Category	Sample plots	Percent of total	Area \ ha	Percent of total
Forest and tree cover	118	62.1	1111804	57.5
Agriculture and bare land	72	37.9	823415	42.5
Closed forest	10	5.8	82075.1	4.2
Open woodland	52	27.4	510045.9	26.4
Scattered trees and shrubs	56	29.5	519683.2	26.9

Table 5.9 shows the close similarity between the result of ground inventory (2004) and the land sat image of 2004 used in land use categories classification. These results indicate the extent of reliability of both methods of data acquired.

The accuracy assessment of the images provided in table 5.7 and 5.8 are indicative of the reliability of the statistics of land classification.

5.6.2 Change in tree species distribution and composition

Table (5.3) and Figures (5.1 and 5.2) indicate clearly that tree cover exist in dynamic changes in area and spatial distribution over the ten years period 1994-2004. These changes are associated with tree clearance and agricultural practices over the whole study area of 1918216.6 hectares. Ground inventory resulted in distribution and measurement of 118 sample distributed over the study area. Analysis of the118 sample plots was based on grouping of the tree species by average dbh classes.

Table (5.10) shows that the distribution of *Acacia seyal* covered almost the whole area as indicated by the occurrence of the species in 100% of sample plots of the diameter classes 7. 0 - 9.9, 10.0 - 12.9, 13.0 - 15.9, and 16.0 and above, (Table 5.10). *Acacia seyal* distribution is 100% over the area indicating high rate of regeneration and development with time.

The distribution of *Acacia senegal* and B*alanites aegyptiaca* indicates remarkable changes with increasing dbh classes from 7.0 up to ≥16.0. *Acacia senegal* indicates wide area distribution in young stands of 7.0-9.9 cm recording 75% distribution within the area represented by 7.0-9.9 cm dbh classes (Table 5.10). Its distribution decreases with increasing diameter size class, recording 70.2%, 45.5% and 18.2% within the area represented by dbh classes (10.0-12.9 cm), (13.0-15.9 cm) and the class (≥16.0) respectively. The distribution trend of the species *Acacia senegal* seems to be enhanced by agricultural practice, while the distribution of *Balanites aegyptiaca* depends on development stages of size classes.

High rates of regeneration of *Acacia senegal* may be developed following agricultural practice while *Balanites aegyptiaca* diameters dominates over *Acacia senegal* as regeneration stands develop with time.

Table (5.10) Species distribution in percent classified by dbh groups

dbh class cm	No. plot %	*Acacia* seyal %	*Acacia senegal %*	*Balanites aegyptiaca %*
7.0-9.9	48	100	75	20.8
10.0-12.9	47	100	72	12
13.0-15.9	12	100	45.5	90
≥16.0	11	100	18.2	83.3

Species composition regarding the three species *Acacia seyal, Acacia senegal and Balanites aegyptiaca* is following similar trend as their distribution, (Table 5.10). *A. seyal* trends to maintain its composition at 60.0-62.0% for all the groups of dbh classes (Table 5.11). *A. seyal* is the dominant species over the range of dbh classes.

Table (5.11) Species composition in percent for the dbh classes 7.0 cm to ≥16.0 cm

dbh class cm	Number of sample plot	*Acacia* seyal %	*Acacia senegal %*	*Balanites aegyptiaca* %
7.0-9.9	48	62.3	21.0	16.7
10.0-12.9	47	60.2	19.3	20.5
13.0-15.9	12	61.5	10.7	21.8
≥16.0	11	62.1	2.7	36.2

Acacia senegal shows that in the composition it tends to decrease with increasing size-classes. Percentages of the composition at 21.0% for dbh class 7.0-9.9 cm and constitute 19.3% for the dbh class 10.0-12.9. The species share in the composition declines to 10.7 % for the dbh class 13.0-15.9 cm and declines to only 2.7% for stands with dbh class of ≥16.0 cm.

Balanites aegyptiaca on the other hand follows a reversed trend to that of *A. senegal.* The percent composition of *Balanites aegyptiaca* is 16.7 for dbh class range 7.0-9.9 cm increasing to 20.5% and 21.8% for dbh class range 10.0-12.9 cm and 13.0-15.9 cm respectively. Then *Balanites aegyptiaca* reaches an average of 36.2% for the dbh class size classes' ≥16.0 cm. *Balanites aegyptiaca* becomes the second dominant species for stands of large size-classes, in a composition where A.seyal is the dominant species.

There may be various reasons to explain the increasing trend for *Balanites aegyptiaca* distribution and composition percent in the natural stands. Harrison and Jackson (1958) described the area as belonging to the *Acacia seyal- Balanites aegyptiaca* savanna. The environment may be suitable for the growth and development of these two species that makes them the most dominant species in association defined in their namely (ibid).

Balanites aegyptiaca is characterized by its ability to reproduce by suckers. Off-springs developing from suckers grow fast and contribute in increasing the species percent share in the species composition (Belephontane 2000). It is known that species capable to develop through suckers increase the stand stock and the species share in the composition of savanna woodland (ibid).

However, *Balanites aegyptiaca* is also known to develop shoots after heavy browsing and hence has the ability to withstand heavy grazing and browsing as mentioned by key informant people of the area questioned through PRA, (Wani 2007). *Acacia senegal* on the other hand is fragile to heavy grazing by animals including wild rodents (Seifildin 1970).

Wani (2007) mentioned that *Acacia senegal* is known for the local communities for production of gum arabic and for durable building poles and good quality fuel. That may be a strong reason that the local communities fell the *Acacia senegal* species for poles and fuel.

The results show that the *Balanites aegyptiaca* was one of the main species in the study area as closed forest, which equal to 53348.78ha. *Acacia seyal* is major species in study area as closed forest . However the *Acacia sengal* was found in small percentage in the closed forest category which confirms the description of (Herrison and Jakson, 1958) that shows the belt of *Balanites aegyptiaca* and *Acacia seyal*.

5.7 Biomass and Carbon change at the study area

The dynamic of land categories changes resulted in forest and tree cover changes which is a result of transfer from one land category to another. The transfer, in fact, resulted in an increase of the area of woodland category by (120183.1) hectares while resulted in decrease of the area of closed forest category by (56481.5) hectares and area of scattered trees and shrubs category by (72133.6) hectares. All these transfers produced changes in woody biomass and carbon stock.

5.7.1 Biomass

Table 5.12 provides inventory results and summaries of tree number stocks per hectare and average volume in cubic meter per tree and per hectare by forest cover categories. The process was completed to summarize total volume by forest cover category for the years 1994 (Table 5.12) and 2004 (Table 5.13)

Table (5-12) volume of wood for forest classes of study area (1994)

Categories of forest	Tree-number-ha	Average cu.m^3\tree	Volume\m^3	Total area \ha	Total Volume \m^3 (x 1000)
closed forest category	140	0.75	105	138556.6	14549
woodland category	70	0.45	31.5	389862.8	12281
Scattered trees and shrubs category	40	0.50	20.0	591816.8	11836
Total					38666

Table (5-13) Volume of wood for forest classes of study area (2004)

Categories of forest	Average Tree number per ha	Average volume\tree in cu.m	Volume per ha in cu.m	Total area per ha	Total volume in cu.m (x 1000)
closed forest category	140	0.75	105	82075.1	8618
woodland category	70	0.45	31.5	510045.9	16065
Scattered trees and shrubs category	40	0.5	14	519683.2	10394
total					35077

Table 5.14 shows the transition of closed forest to other land cover and implies a amount of wood volume loss. Total of volume lost from wood volume of closed forest and trees and shrubs were more than gain of wood from woodland.

Table 5.14 Losses in term of wood volume

Categories of forest	Volume 1994 cu.m (x 1000)	Volume 2004 cu.m (x 1000)	Net loss cu.m
Closed forest category	14549	8618	- 5931
Open woodland category	12281	16065	+ 3784
Scattered trees and shrubs category	11836	10394	- 1442
Net loss			3589

The reduction could be considered as negative in terms of wood content. Changes in total growing stock reflect the combined effects of changes in forest area and in growing stock per hectare.

5.7.2 Carbon stock at the study area

Conversion of volume stock to biomass and carbon stock changes were calculated following El siddig (2006) using default Figure for conversion process. Table (5.15) shows the results of conversion from wet volume to dry mater and to carbon stock change by category as loss or gain using (0.5) as a default figure conversion factor for conversion of volume into dry biomass and for conversion of biomass into carbon content.

Table (5-15) Volume net change and carbon content

Categories of forest	Volume in cu.m (x 1000)	Volume in cu.m (x 1000)	Net change cu.m. (x 1000)	Carbon content Kg
Closed forest category	14549	8618	- 5931	296505
Open woodland category	12281	16065	+ 3784	1892
Scattered trees and shrubs category	11836	10394	- 1442	721
Total				-1794

The present study is providing a procedure for the evaluating direction of the trend of changes in forest and tree cover and their dynamics in relation to land use system in an important area in southern region of Sudan. As it has been possible to identify three categories of forest and tree cover, dynamic changes within and between these categories has been used in the context of addressing indicators as tools for monitoring changes. Most important is the use of indicators that address issues related to climate change.

Deforestation in tropics constitutes one of the most important issues related to climate change. In the present study, deforestation has been indicated to occur in a process involving forest degradation that precede the process of deforestation. Forests degradation takes place as result of selective logging in closed forest and land transfer from closed forest category to open woodland category or scattered trees and shrubs category. Because dynamic change takes place in both directions (Figure 5.13), forest degradation is associated with forest rehabilitation resulting from tree regeneration whereby, the scattered trees and shrubs category improved in stocking to develop into open woodland to closed forest through rehabilitation process.

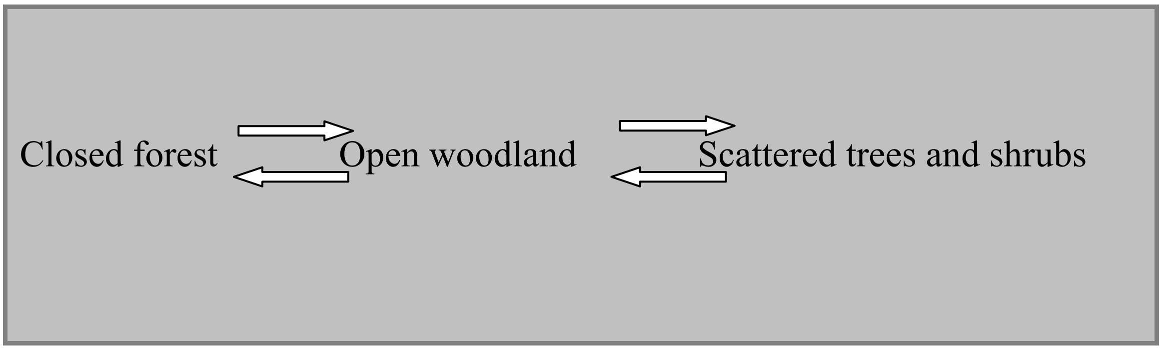


Figure (5.13) Two direction processes of degradation and rehabilitation

Table 5.3 provides clearly indicators of the dynamic changes within and between the three categories of forest and tree cover. The process of degradation is usually human induced and can be controlled through organized management and prevention of forest selective logging.

However, the process of rehabilitation is natural, based on natural regeneration. In fact periodic surveys within short periods are needed to follow and understand the potential factors that enhance regeneration in order to control and manage them. Unfortunately, the successive measurements carried in the present study did not provide for such follow up as they were located at two points in time ten years apart; namely 1994 and 2004.

Although the actual loss in forest and tree cover over ten years was so large, great part of the loss was compensated for by the process of rehabilitation. The conclusion drawn from these dynamic changes is that it may be possible to control the changes by understanding the causes, which could be performed by shortening the periods of measurements and recording the factors enhancing regeneration.

Forest and tree cover degradation does not stop at the level of degradation, but progresses in the direction of complete clearance in preparation of land for agriculture. The deforestation that takes place as a result of complete clearance of trees of the three categories (closed forests, open woodland and scattered trees and shrubs) is a human activity induced by need for food. As in the case of degradation, deforestation is associated with forest expansion resulting from natural regeneration.

However, both processes of degradation and deforestation contribute to climate change in two ways. These processes result in the reduction of the green house gases sinks and at the same time play as source for green house gasses emissions as a result of burning of wood.

However, the dynamic changes which involve losses of forest cover associated with gains of forest cover indicate the need for understanding of the mechanisms that facilitate the gain so as to enhance more gain. The mechanism through which gain of forest cover is performed increases the chances for mitigation of green house gas in the atmosphere. Forest cover gains take place through forest expansion that occurs as a result of regeneration processes whether natural or through artificial reforestation.

The forest cover loss or gains has been measured by analysis of remote sensing images and land use categories identification. Results show land cover types including closed forest, open woodland and scattered trees and shrubs. The results based on remote sensing images did not provide details on species changes.

However, ground survey involved tree species records and changes. The three main species included are *Acacia seyal, Acacia sengal* and *Balanites aegyptiaca*. The results show areas of regeneration potentials and gradual change of species composition the following stand development.

CHAPTER SIX

Conclusions and Recommendations

6.1 Conclusions

- The results show the close similarity between the result of ground inventory (2004) and the land sat image of 2004 used in land use categories classification. These results indicate the extent of reliability of both methods of data acquired.
- The indicators used in the present study are defined by "Extent of area by forest type relative to total forest area and land use area". Observation of forest cover extent indicates that the forest cover is spatially changing from large tracts. However, it seems necessary to use selected biological indicators to evaluate the extent of change of forest land and other land categories when displayed in maps at the specific times defined in the present study at 1994 and 2004 using land sat images.
- The results show the total net changes in land use whether positive or negative between 1994 to 2004. The forest area detected between two points of time is not usually a sustainably existing forest cover. Forest is cleared while regeneration may take place. It appears from that net change in land use classes varies over time as increasing or decreasing. However, it seems that analysis of land

use changes over long time may show a gradual average annual change in a positive or negative change.

- The results show that *Acacia seyal* is major species in study area as closed forest and the *Balanties aegyptiaca* was one of the main species. However the *Acacia sengal* was found in small percentage in the closed forest category.
- Although the actual loss in forest and tree cover over ten years was so large, great part of the loss was compensated for by the process of rehabilitation. The conclusion draown from these dynamic changes is that it may be possible to control the changes by understanding the causes, which could be performed by shortening the periods of measurements and recording the factors enhancing regeneration.
- Deforestation in tropics constitutes one of the most important issues related to climate change. In the present study, deforestation has been indicated to occur in a process involving forest degradation that precedes the process of deforestation.
- Forest degradation takes place as a result of selective logging in closed forest and land transfer from closed forest category to open woodland category or scattered trees and shrubs category. Because dynamic change takes place in both direction, forest degradation is associated with forest rehabilitation resulting from tree

regeneration whereby, the scattered trees and shrubs category improved in stocking to develop into closed forest through rehabilitation process.

- Processes of degradation and deforestation contribute to climate change in two ways. These processes result in the reduction of the green house gases sinks and at the same time play as source for green house gasses as result of burning of wood.

6.2 Recommendation

- The government at the national level should take serious notice and be aware towards the study area where obvious change of forest cover was detected. It should establish a specialized unit or sector to follow the world schemes.
- Government should put regulations to modify forest policy and laws to deal with forest conservation and management in area experiencing development of oil industry within the Savana region.
- Environmental Impact Assessments should be an important issue.
- Assessment of the impact of oil exploitation in northern Upper Nile.
- Assessment should consider physical safety, economic sustainability, land rights and human rights, and the provisions and the purpose of the Sudan Comprehensive Peace Agreement.
- Forest and environmental manegemant should consider Involvemen of government and civil society organisations.
- Environmental impact assessment should be shared with all stakeholders and the wider public, to implement its recommendations, and to evaluate and update it on a regular basis.
- It is recommended that authorities should adopt adequate standards and establish firm procedures that assure that its operations do not contribute to environmental degradation.

- Social interaction within the study area should be done because due to security reasons the study was carried out without social identification and analysis to view all the aspects of forest assessment resource.
- Annual survey should be done to assess, the periodic change factors and to monitor the diagnostic results of agricultural land changes.

Reference

Alex de Sherbinin, 2002**.** A collaborative effort of SEDAC and the IGBP/IHDP LUCC Project September 2002. Center for International Earth Science Information Network (CIESIN), Columbia University, Palisades, NY, USA. Email: adesherbinin@ciesin.columbia.edu.

Ahlcrona, S. E. 1988. The Impact of Climate and Man on Land Transformation in Central Sudan. Application of Remote Sensing, Dep. Of physical Geography, Royal University of Lund, Lund University Press, Sweden.

Ali, M.M. 1996. Assessment and Mapping of Desertification in Western Sudan Using Remote Sensing Techniques and GIS. M.Sc. thesis, University of Khartoum, pp. 169.

André Oosterman and Manggala Wanabakti, 2000 Jakarta Carbon Trading for Sustainable Forest Management The Case of the Berau Model Forest Berau Forest Management Project (BFMP) October 2000.

A, A. MOHAMMED. 2003**.** Forestry Outlook Study for Africa (FOSA), 2003: 18.

Appanah, S., Krishnapillay, B. and Dahlan, K. 2000. Sustainable Production of Forest Products in the Humid Tropics of Southeast Asia: Latest Developments. In: Krishnapillay, B., Soepadmo, E., Arshad, N.L., Wong, H.H., Appanah, S., Wan Chik, S., Manokaran, N., Hong, L.T. and Khoo, K.C. (eds.) *Forests and Society: The Role of Research Sub-Plenary Sessions Volume 1*, pp.201-210. (XXI IUFRO World Congress: Kuala Lumpur)

Campbell, B.J. 1996. Introduction to Remote Sensing. second edition. Teylor and Francis, London.

Chen et al. 2003.

CICI, 2003. International Conference on the Contribution of Criteria and Indicators for Sustainable Forest Management: The Way Forward (CICI-2003). Volume 1. 3 - 7 February 2003, Guatemala City, Guatemala.)(Report: FAO/ITTO Expert Consultation on Criteria and Indicators for Sustainable Forest Management. 2 - 4 March 2004, Cebu City, Philippines)

CIFOR, 2003**.** The Way Forward. Volume 1: 3-7 February 2003, Guatemala.

Coauthors, 2000. The case of the missing sink, work publisher. April 20, 2000 | url =http://www.mcgill.ca/reporter/32/15/roulet/ | format = | doi = | accessdate = 2007-02-23}}</ref>.

Coauthors, 2001. Soil Science - Abstract: Volume 166(11) November 2001 p 858-871 SEQUESTRATION OF CARBON BY SOIL, work publisher. =November 2001 .

Conservation Commission of Western Australia (C.C.W). 2002, A new forest management plan for Western Australia. Discussion paper, January 2002. Conservation Commission of Western Australia, Perth.

Cost, N.D., Howard, J., Mead, B., McWilliams, W.H., S W.B., Van Hooser, D.D., Wharton, E.H. 1990. The biomass resource of the United States. U.S. Department of Agriculture, Forest Service, General Technical Report W0-57 Washington, DC. 21pp.

Campbell, B.J. 1996. Introduction to Remote Sensing second edition. Teylor and Francis, London.

Cowbell, J. E. 1981. land sat features enhancement or can we separate vegetation from soil. Proceeding, of 15 the international symposium on remote sensing, pp 599- 621.

Cracknell, A. P. and Hayes L.W. B. 1991. Introduction of remote sensing London: Talar and Francis.

DaaK, A. A. 2007. Detection of venation cover change using remote sensing and GIS system Msc thesis university of Khartoum, faculty of forestry.

Dargavel, J. 1995. *Fashioning Australia's forests.* Melbourne, Oxford University Press.

Dixon, R.K., J.K. Winjum, K.J. Andrasko, J.J. Lee, and P.E. Schroeder. 1994. Integrated Land-Use Systems: Assessment of Promising Agroforest and Alternative Land-Use Practices .

Dry land Husbandry in the Sudan. 1996. OSSREA, Workshop Report, DHP, Sudan.

ElAmin, H. M. 1990.Trees and Shrubs of the Sudan. Itheca Press, Exter, Oxford

El-Moghraby, Asim I. 2006. The State of the Environment in the Sudan, Fifty Years After Independence, paper presented at the 7th International Sudan Studies Conference.

Elsiddig, E. A., **Elyas, A. E. and Elfadile, B**. 2005. The application of technology for detection of forest cover change to facilitate decisions on management option . Proceeding for interaction work shop on space technology Sudan 26-29 November 2005.

Elsiddig, E. A. 2006. Tree measurement in Sudan, University of Khartoum press :159 (in Arabic).

Elsiddig, E. A. and Hietheringtin, J. C. 1985. The stem and branch volume of *Acacia nilotica* in the Fung region in the Sudan. University college of North Wales, Department of forestry and wood science, publication

Environmental and Health Act, 1975. (Sudan).

ERDAS IMAGINE 8. 6. 1982. User guide for windows. Leica Geosystems GIS and Mapping Division. ERDAS LLC. Atlanta, Georgia.

ERDAS Inc. 1994. Erdas Field guide. 3rd edn, Atlanta: Erdas Inc. 627

Fact on Sudan , 2000 . The European Coalition on Oil in Sudan (ECOS) is a group of over 80 European organizations working for peace and justice in Sudan ECOS. www.ecosonline.org .

Fact on Sudan, 2003. The European Coalition on Oil in Sudan (ECOS) is a group of over 80 European organizations working for peace and justice in Sudan ECOS. www.ecosonline.org .

FAO, 2001. Global forest resources assessment 2000. Main Report. FAO Forestry Paper 140. Rome. 479 pp.

FAO, 1993**.** The challenge of Sustainable Forest Management, Rome.

FAO, 1994. Evaluation of forestry resources 1990 - Non-tropical developing countries, Mediterranean Region - FO: MISC/94/3. Rome. 48 pp.

FAO, 1995. Forest resources assessment 1990 - Non-tropical developing countries. Technical Report (FO: GPC/INT/474/FRA - FO: GCP/INT/475/NET). Rome. 152 pp.

FAO, 1996. Forest resources assessment 1990 - Survey of tropical cover and study of change processes. FAO Forestry Paper 130. Rome. 152 pp.

FAO, 2002. Evaluation of world forestry resources 2000. Main Report. FAO Study: Forests 140. Rome. 466 pp.

FAO/ITTO, 2004. Expert Consultation on Criteria and Indicators for Sustainable Forest Management. 2 - 4 March 2004, Cebu City, Philippines).

Finegan, B. and Campos, J.J. 2000. Criteria and Indicators for The Assessment of Sustainability at The Forest Management Unit Level-A Neotropical Perspective. In: Krishnapillay, B., Soepadmo, E., Arshad, N.L., Wong, H.H., Appanah, S., Wan Chik, S., Manokaran, N., Hong, L.T. and Khoo, K.C. (eds.) *Forests and Society: The Role of Research Sub-Plenary Sessions Volume 1*, pp. 275-287. (XXI IUFRO World Congress: Kuala Lumpur)

Finkel, H. J. 1986. Semi- arid and Water Conservation. CRC press, Boca Raton, Florida, USA, 126pp.

FNC 1989. Forest National Corporation, FNC 1989 Forest Act.

FNC 1998. Forest National Corporation, national forest inventory in Sudan. FAO project Sudan. GCP/SUD/033, Khartoum.

FNC 2000. Forest National Corporation annual report, technical department , Khartoum.

FNC 2003, Forest National Corporation annual report, technical department , Khartoum.

Forests Act, 1989. (Sudan).

FRA. 1996. *Forest resources assessment 1990 - Survey of tropical cover and study of change processes.* FAO Forestry Paper 130. Rome. 152 pp.

FRA, 2000. The Global Forest Resources Assessment 2000 (FRA 2000): Main Report. FAO forestry paper 140. 479 p.

FRA. 2001. *Global forest resources assessment 2000*. Main Report. FAO Forestry Paper 140. Rome. 479 pp.

FRA. 2001. *Global forest resources assessment 2000*. Main Report. FAO Forestry Paper 140. Rome. 479 pp.

FOSA, 2001. forestry outlook study in Africa 2001 Sudan country outlook / FNC-FAO. Forest outlook study for Africa

FRA, 1990**.** Global Forest Resources Assessment 1990, FAO, Rome.

FRA, 2000**.** Global Forest Resources Assessment 1990, FAO, Rome.

FRA, 2005**,** Methodology of information generation and management for FRA 2005 (E)

FRA, 2005. Global assessments of growing stock, biomass and carbon stock (E)

FRA, 2005. Lessons learned and suggestions for future assessments (E)

FRA, 2005. Documentation of calculations to determine progress towards sustainable forest management in the FRA 2005 main report (E)

Franklin, 2000.

Froylán Castañeda, Christel Palmberg-Lerche and Petteri Vuorinen, 2001. Criteria and Indicators for Sustainable Forest Management: A Compendium. Paper compiled by Forest Management Working Papers, Working Paper 5. Forest Resources Development Service, Forest Resources Division. FAO, Rome (unpublished).

Guzman, Diane de, and Egbert G.Ch. Wesselink, 2002. *Depopulating Sudan's Oil Regions,January to March 2002*, European Coalition on Oil in Sudan, Utrecht, May 2002.

Geist, H. and Lambin E. 2001. Proximate Causes and Underlying Driving Forces Of Tropical Deforestation. *Bio Science*, vol. 52: 143-150.

Gorani and Khair, 2005.

Green, J. A. I EL Mograby & O. M. M. Ali 1984. A faunsitic econnaissance of lakes Kundi and Keliak, Western Sudan. Hydrobiologia,110,pp.33-44.

Harmer, R. and Willoughby, I. 2007**.** Controlling bramble within an oak woodland using herbicides. *Aspects of Applied Biology* 82: 165-173.

Harrison, **N. N.** ***and*** **Jachson, J.K.** 1953. Ecological classification of the vegetation of the Sudan. Khartoum, Ministry of Agriculture, Forest Bulletin No.2.

Haynes, R.W., Stevens, J.A. and Barbour, R.J. 2000**.** Criteria and Indicator For Sustainable Forest Management at the U.S.A. National and Regional Level. In: Krishnapillay, B., Soepadmo, E., Arshad, N.L. 2000.

Hill *et al*. 1998

Holdridge, L.R. 1967**.** Life zone ecology. Revised Edition, Tropical Science Center, San Jose, Costa Rica. 206p.

Houghton, R.A., Schlesinger, W.H., Brown, S., and Richards, J.F. 1985. Carbon dioxide exchange between atmosphere and terrestrial ecosystems.

IIED / IES, 1990.

International Training Center, 1997. M.SC. Course on Geographic Information System. Earth Recourses Surveys, Enschede,- 154pp.

International Tropical Timber Organization Center, 2002. Forest Certification: Pending Challenges for Tropical Timber. ITTO Technical Series No. 19. International Tropical Timber Organization. ITTO: Yokohama.

International Tropical Timber Organization Center. 1998**.** Criteria and Indicators for Sustainable Management of Natural Tropical Forests. ITTO Policy Development Series No. 7. International Tropical Timber Organization. ITTO: Yokohama.

IPCC. Assessment Report , 1996**.** Responding to this request, the IPCC adopted assessment report on 30 August 1996 in Sundsvall, Sweden.

IPCC, 2000. National Greenhouse Gas Inventories Programme TSU Institute for Global Environmental Strategies 2108-11 Kamiyamaguchi, Hayama, Kanagawa 240-0115 Japan. **E-mail:** mail: http://www.ipcc-nggip.or.jp/mail

IPCC, 2007. Forestry In Climate Change 2007. Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the

Intergovernmental Panel on Climate Change, Nabuurs, G.J., O. Masera, K. Andrasko, P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T.Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, X. Zhang, 2007. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Janza, F. J. 1975. Manual of Remote Sensing Volume (1), 1st edition. Published by American Society of Photogrammetry, Virginia.

Jensen, J.R. 1996. Introduction to Digital Image Processing, Second Edition. Upper Saddle River, NJ: Prentice Hall.

Jensen, J.R. 2000. Remote Sensing of the Environment: An Earth Resource Perspective. Upper Saddle River, NJ: Prentice Hall.

Kennedy, P.J. 1989. Monitoring the Phonology of Tunisian Grazing lands. Remote sensing, 835-845.

Kleinn, C. 2000. Estimating metrics of forest spatial pattern from large area forest inventory cluster samples. *Forest Science*, 46(4): 548-557.

Koch, P. 1989. Estimates by species group and region in the USA of: I. Below-ground root weight as a percentage of ovendry complete-tree weight; and II. carbon content of tree portions. Consulting report. 23pp.

Kokusai, R. K. K. 1996. Steps toward sustainable forest management (Japanese), 454pp.

Lanly, J.P. 1982. Tropical forest resources, FAO Forestry Paper no. 30, Rome.

Lillesand, **T. M and Kiefer, R. W.** 1994. Remote Sensing and image interpretation 3rd edition, John Wiley & Sons inc., New York, USA.

Lillesand, T. M. Ralph, W. Kiefer. 2000. Remote Sensing and Image Interpretation, Fourth edition, John Wiley and Sons. New York.

Marland, H. 1986. *North African forestry resources*. Working document. FAO Rome. 34 pp.

Marland, H. 1987. Near Eastern forestry resources. Working Document. FAO Rome. 31 pp.

Marland, H. 1988. The Prospect of solving the CO_2 Problem Though Global Reforestation. U.S. Department of Energy, Office of Energy Research, Carbon Dioxide Division.

Moran *et al*., 1994

Moran, E. and E. Brondizio. 1998. Land use Change After Deforestation in Amazonia. In: People and Pixels, D. Liverman, E. Moran, R. Rindfuss, and P. Stern 1998 (eds.). Washington, DC: National Academy Press.

Moulton, R. and K. Richards. 1990. Costs of Sequestration Carbon Through Tree Planting and Forest Management in the United States. U.S. Department of Agriculture Forest Service General Technical Report WO-58.

Olsson, L. 1985. An integrated Study of Desertification, Application of Remote Sensing, GIS and Spatial Models in Semi- arid land, Sudan. Dep. Of Physical Geography, Lund University Press, Sweden.

Parks, P.J. and I.W. Hardie, 1995. Least-Cost Forest Carbon Reserves: Cost Effective Subsidies to Convert Marginal Agricultural Land to Forest. Land Economics 71.

Plantinga, A.J., T. Mauldin, and D.J. Miller, 1999. An Econometric Analysis of the Costs of Sequestering Carbon in Forests. *American Journal of Agricultural Economics* 81:812.

Poore, D. 1989**.** No Timber without Trees. Earthscan Publications Ltd.: London.

Saamin, S. and Rahman, A. R. 1998. Domestication of Jungle Tree Species for Multipurpose Uses. *The Planter* 74 (871): 561-572.

Sabins, F.F. and Floyd. A. S. 1996. Remote Sensing Principle and Interpretation (3d edition). W. H. Freeman and Company, New York, 494p.

Salaheldin, G. H. 1991. Environmental Degradation in Semi-arid Rangeland in Northern Sudan. Desertification contra Bulletin No 19, (UNEP).

Salleh Mohd. Nor and Michael V. Galante. Paper presented at the 13th Science Conference of the Islamic Academy of Science (IAS): 29 September-2October 2003, Kuching Hilton Hotel,

Schreuder, H. 2001. Sampling using thematic mapping, very large scale photography, and ground sampling for measurement and strategic surveys. In *Forest biometry, modelling and information science*. Proceedings of IUFRO 4.11 conference, London, UK, June 2001.

Singh, A. 1989**.** Digital Change Detection Techniques Using Remotely Sensed Data. *International Journal of Remote Sensing* 10 (6): 989 - 1003.

Stocking, M. and Murnaghan, N. 2001. Handbook for field Assessment of Land Degradation. Earthscan Publication Limited; London, Stering, UK.

Stokes, V.J. and Willoughby, I. 2007. Tolerance of trees to foliar acting herbicides. *Aspects of Applied Biology* 82: 91-101

Stow, D.A., L.R. Tinney and J. E. Estes. 1980**.** Deriving land use/land cover change statistics from landsate: a study of prime agricultural land. In Proceedings of the 14th International Symposium on Remote Sensing of Environment, Ann Arbor, M.I. Environmental Research Institute of Michigan, Ann Arbor, M. I. pp1227-123.

The Central American Process of Lepaterique, 1997. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6, 51-70. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The Dry Zone Africa Process, 1997. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 95-104. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The Economist, December 1, 2005**.** News paper**.**

The Helsinki Process, 1995. . In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 51-70. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The ITTO Process, 1997. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 115-124. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The Montreal Process, 1995. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 19-50. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The Near East Process, 1997. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 105-114. (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

The Tarapoto Proposal, 1995. In proceeding of the XI world forestry congress, Turkey, 1997, Vol. 6: 71-86 (http://193.43.36.7/WAICENT/FAOINFO/FORESTRY/wforocong/PUBLI/V6?DEAFAULT.HTM#TOP).

Unasylva - No. 210, 2000 .*An international journal of forestry and forest industries* - Vol. 53 2002/3.

UNCED, 1992. Report, through the conference , New York : United Nation

UNCOD, 1977. Reproduced, with permission, from: United Nations Conference on Desertification

UNCOD, 1978. Round-up, plan of action and resolutions. New York: United Nations.

UNECE/FAO, 2000. *Forest resources of Europe, CIS, North America, Australia, Japan and New Zealand*. Main Report. ECE/TIM/SP/17. Geneva. 445 pp.

Weismiller, R. A. Kistoof, S. J. D. K. 1977. Change detection in costal zone environments. *Photogrammetric engineering and remote sensing*, 34: 1533- 1539.

Williams, J. R, 2004. Addressing global warming and biodiversity through forest restoration and coastal weltlands creation. Science of The Total Environment 240, 1-9.

Wildfife Conservation and National Parks, 1987 (Sudan).

World Bank 1996**.** Environmental Assessment Source Book. Three Volumes. World Bank Publications.

Xu, H., Wang. X. and G. Xiao, 2000. A remote sensing and GIS integrated study on urbanization with its impact on arable lands: Fuqing City, Fujian Province, China. *Land Degradation & Development*. Vol. 11, Iss. 4: 301-14.

Appendences.

Appendix (3.1) Vegetation cover at the study area

Name	Life Form	Remarks and economic uses.
Brachiaria deflexa	Grass	Medium height herb on shallow flooded clay soil use for grazzing
Brachiaria obtusiflora	Tall grass	Found on dark cracking clay soil subject for flooding used as forage.
Chloris lamparoparia	Short grass	Favours flooded clays.used for grazing.
Commelina spp.	Running forb.	Grows on edge of the wet clay soil used for grazing.
Cymbopogon nervatus	Tall grass	Found on wet coditons of the clay soil ,used for grazing when dry.
Cymbopogon poximus	Tall grass	Found on wet darking clay soil,tolerates flooding,used for grazing when dry and after burning.
Chorchorus spp.	Medium forb.	Favours shallow flooded site on clay soil,used as human food and also grazed.
Cyperus spp.	Grass-like	Favours low lying sites-flooded with

		water ,used for grazing and human body smoke.
Dactyloctenium acgyptium	Short,running and erect grass	Favours edege of wet soil, used for grazing and human food during famine.
Nymphia lotus	Water forb.	Favours stagnant water-tubers used as human food.
Oryza longstaminata	Medium water	Favours stagnant water,grazed heavily.
Rhyncosia memnonia	Runner legume forb.	Grows on the edege of moist sites-grazed by all animals.

Appendix (3.2) Important trees spp. at the study area

Name	Life form	Remarks and ecomonic uses.
Acaia seyal	Tree	Found dense in flat ans low lying flooded areas of dark creaking clay soil,used as fuel wood,charcool ,building material ,birds nesting habitat and shade.
Acaia polyacantha	shrub	In flat clay soil subject to flooding.used as fencing material and building .
Acaia gerrardii	Tree	Found in flat clay soil shallow flooded –rare,used as fuel wood and nesting.
Balanites aegyptica	Tree	On dark cracking flooded clay soil,uses are for household and agriculture implements,fuel wood,forage,fencing and oil form fruits.
Calortropis procera	Shrub	Grows on shallow flooded sites,grazed and browsed by sheep and goats.
Ziziphus spin christi	Shrub/tree	Favours the fringes of wet sites ,grazed and browsed by livestock-goats and human eat the fruits.
Acacia sengalensis	Shrub/tree	Favours the mixed sand clay dry area, used as economic crop for gum Arabic production, charcoal production and fencing material.

Appendix (3.3). Air photo for Adar yale area

Appendix (3.4). Air photo for Paloich area.

Appendix (3.5) questionnaire about study area for local people and authorize people

1- personal information

(a) age : 20- 30 years old	25 %
(b) age : 30- 50 years old	34 %
(c) age : over 51 years old	41 %

Work type :

(a) governmental employ	10 %
(b) private .	90 %

Land use activities:

(a) farmer .	23 %
(b) animal owners .	46 %
(c) forest activities.	31 %

2- Areas description:

Forest type by location	Open wood land	Scattered trees and shrubs	Closed forest	Bare land
	27 %	33 %	10 %	30 %
Type of forest activities	Fuel wood and charcoal production	Arabic gum production	Traditional agriculture	Pasture
	56 %	5 %	20 %	19 %
New activities	Mechanization of agriculture	Furniture production	Road construction	Fishing
	66 %	11 %	13 %	10 %

GLOSSARY

Forest land

Land at least 10 percent stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at leas t 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest type

A classification of forest land based on the species presently forming a plurality of the live-tree stocking.

United Nations Convention on Climate Change (UNFCCC):

The convention was adopted on 9may 1992 in New York and signed at the 1992 Earth Summit in Rio de Janerio by more than 150 countries and the European Community.

Kyoto Protocol:

The Kyoto Protocol to the united Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Third Session of the Conference of the Parties to the UNFCCC in 1997 in Kyoto,Japan.The Kyoto Protocol has not entered into force as of April 2002.

Emissions:

In the climate change context,emission refer to the release of greenhouse gases and or their precursors and aerosols into the atmosphere over a specified area and period of time.

FRA 1990, 2000, 2005: Forest Resources Assessment. International forest assessment by FAO forestry department

Tree: A woody perennial with a single main stem, or in the case of coppice with several stems,having a more or less definite crown.Includes: bamboos, palms and other woody plants meeting the above criterion.

Shrubs:

Refer to agricultural land types where the dominant woody elements are shrubs i.e. woody perennial plants, generally of more than 0.5 m and less than 5 m in height on maturity and without a definite crown. The height limits for trees and shrubs should be interpreted with flexibility, particularly the minimum tree and maximum shrub height, which may vary between 5 and 7 m approximately.

The IPCC

is a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP). Its constituency is made of :

- The governments: the IPCC is open to all member countries of WMO and UNEP. Governments of participate in plenary Sessions of the IPCC where main decisions about the IPCC workprogramme are taken and reports are accepted, adopted and approved. They also participate the review of IPCC Reports.
- The scientists: hundreds of scientists all over the world contribute to the work of the IPCC as authors, contributors and reviewers.
- The people: as United Nations body, the IPCC work aims at the promotion of the United Nations human development goals

Forest degradation:

Takes different forms, particularly in woodland formations, deriving mainly from human activities such as overgrazing, overexploitation (for fuelwood or timber),repeated fires, or due to attacks by insects, diseases, plant parasites or other natural sources such as cyclones. In most cases, degradation does not show as a decrease in the area of woody agricultural land but rather as a gradual reduction of biomass, changes in species composition and soil degradation. Unsustainable logging practices can contribute to degradation if the extraction of mature trees is not accompanied with their regeneration or if the use of heavy machinery causes soil compaction or loss of productive forest area.

Growing stock:

Stem volume of all living trees more than 10 cm diameter at breast height (or above buttresses if these are higher), over bark measured from stump to top of bole.Excludes: all branches.

Deforestation:

The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold. Deforestation implies the long-term or permanent loss of forest cover and implies transformation into another land use

Forest degradation:

Changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services.

Net annual growth

The net increase in the volume trees during a specified year. Components include the increment in net volume of trees at the beginning of the specific year surviving to its end, plus the net volume reaching the minimum size class during the year, minus the volume of trees that died during the year, and minus the volume of trees that became cull trees during the year.

Net volume in cubic meter

The gross volume in cubic meter less deductions for rot, roughness, and poor form. Volume is computed for the central stem at dbh.

Stocking

The degree of occupancy of lands by trees, measured by basal area or number of trees by size and spacing, or both, compared to a stocking standard; that is, the basal area or number of trees, or both, required to fully utilize the growth potential of the land.

Net change

The net difference over given period between increase in area of forest and other wooded land from afforestation and natural extension and loss of such land to other uses.

Growing stock

The living part of the standing volume.

Class

1. A group or category of attribute values; a set of entities possessing certain common attribute values.
2. Pixels in a raster file that represent the same condition.

Classification

The process of sorting or arranging entities into groups or categories based on their attribute values; on a map, the process of representing members of a group by the same symbol, usually defined in a legend.

Clip

In ArcInfo, a command that extracts the features from one coverage that reside entirely within a boundary defined by features in coverage (called the clip coverage).

Column

The vertical dimension of a table. Each column stores the values of one type of attribute for all of the records, or rows, in the table. All the values in a given column are of the same data type; for example, number, string, BLOB, date.

Coordinate system

A fixed reference framework superimposed onto the surface of an area to designate the position of a point within it; a reference system consisting of a set of points, lines, and/or surfaces; and a set of rules, used to define the positions of points in space in either two or three dimensions. The Cartesian coordinate system and the geographic coordinate system used on the earth's surface are common examples of coordinate systems.

Coordinates

Values represented by x, y, and possibly z, that define a position in terms of a spatial reference framework. Coordinates are used to represent locations on the earth's surface relative to other locations.

Data

Any collection of related facts arranged in a particular format; often, the basic elements of information that are produced, stored, or processed by a computer.

Database

One or more structured sets of persistent data, managed and stored as a unit and generally associated with software to update and query the data. A simple database might be a single file with many records, each of which references the same set of fields. A GIS database includes data about the spatial locations and shapes of geographic features recorded as points, lines, areas, pixels, grid cells, or TINs, as well as their attributes.

Density

A quantitative expression of the mass contained per unit volume.

Density Slicing

Density Slicing is the mapping of a range of contiguous grey levels of a single band image to a point in the RGB color cube. The DNs of a given band are "sliced" into distinct classes.

Euclidean distance

The straight-line distance between two points on a plane.

Extrapolation

The inference or calculation of unknown values from values which are currently known

Field

1. A column in a table that stores the values for a single attribute.
2. The place in a database record, or in a graphical user interface, where data can be entered.
3. A synonym for surface.

Geographic information system (GIS)

An arrangement of computer hardware, software, and geographic data that people interact with to integrate, analyze, and visualize the data; identify relationships, patterns, and trends; and find solutions to problems. The system is designed to capture, store, update, manipulate, analyze, and display the geographic information. A GIS is typically used to represent maps as data layers that can be studied and used to perform analyses.

Global positioning system (GPS)

A constellation of 24 radio-emitting satellites deployed by the U.S. Department of Defense and used to determine location on the earth's surface. The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through triangulation. The system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.

Pixel

1. The term is an abbreviation for 'picture element.'

2. In remote sensing, the fundamental unit of data collection. A pixel is represented in a remotely sensed image as a rectangular cell in an array of data values.

3. The smallest unit of information in an image or raster map. Usually square or rectangular, pixel is often used synonymously with cell.